Gold letter

# PETROLEUM INVESTIGATION

# HEARING

BEFORE A

## SUBCOMMITTEE OF THE COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE HOUSE OF REPRESENTATIVES

SEVENTY-SIXTH CONGRESS

ON

## H. Res. 290 and H. R. 7372

TO PROMOTE THE CONSERVATION OF PETROLEUM; TO
PROVIDE FOR COOPERATION WITH THE STATES IN
PREVENTING THE WASTE OF PETROLEUM; TO
CREATE AN OFFICE OF PETROLEUM CONSERVATION; TO AMEND THE ACT OF
FEBRUARY 22, 1935, AS AMENDED,
AND FOR OTHER PURPOSES

NOVEMBER 6, 7, 8, AND 10, AT WASHINGTON, D. C.

Part 1

Printed for the use of the Committee
on Interstate and Foreign Commerce

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UNITED STATES
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# PETROLEUM INVESTIGATION

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## MONDAY, NOVEMBER 6, 1939

House of Representatives,
Subcommittee of the Committee on
Interstate and Foreign Commerce,
*Washington, D. C.*

The subcommittee met, pursuant to call, at 10:30 a. m., in the committee room, New House Office Building, Hon. William P. Cole, Jr., presiding.

Mr. Cole. Gentlemen, the committee will come to order, please.

July 22, 1939, President Roosevelt addressed the following letter to Hon. Clarence F. Lea, chairman of the Committee on Interstate and Foreign Commerce of the House of Representatives:

The White House,
*Washington, July 22, 1939.*

Hon. Clarence F. Lea,
*Chairman, Committee on Interstate and Foreign Commerce,*
*House of Representatives.*

My Dear Mr. Chairman: On February 15, 1939, I transmitted to the Congress a report on Energy Resources by the National Resources Committee, wherein certain recommendations were made relative to oil and gas problems in the United States.

I believe it is consistent with these recommendations to invite the attention of your committee to the desirability of the early enactment of legislation which will provide a coordinated national policy in oil conservation. To my mind, the legislation should be designed to prevent avoidable waste in the production of oil and gas in the United States.

As you know, despite the progress which has been made toward oil conservation under State law and regulation, the production of petroleum is attended by waste. In view of the vital part which petroleum plays in the national defense, as well as its importance in commerce and industry, the prevention of waste in petroleum production should be the subject of an enactment by the Congress.

I appreciate the thoroughness with which the Committee on Interstate and Foreign Commerce conducted the petroleum investigation in 1934 in response to H. R. 441; but in the light of changes that have taken place, I believe the committee may wish to study developments since that time by investigation and hearings prior to the next session of the Congress. To this end, and with a view to the enactment of suitable legislation in the next session, I request that the petroleum conservation bill which I today discussed with you and Representative Cole be introduced at this session.

Sincerely yours,

Franklin D. Roosevelt.

In response to that letter, Resolution 290 was introduced and passed by the House, resulting in the appointment by Chairman Lea of a subcommittee consisting of the gentlemen here this morning.

I am glad again to be with this committee presiding over an interesting and important subject and to find at the outset the same spirit of cooperation from the industry and the Federal Government and all concerned, the States especially, which the committee received in 1934.

The bill referred to in President Roosevelt's letter, which I introduced, is H. R. 7372. I file in the hearing at this time a copy of Resolution 290 and of H. R. 7372.

(The resolution and bill are, as follows:)

[H. Res. 290, 76th Cong., 1st sess.]

### RESOLUTION

Whereas in 1934 the Committee on Interstate and Foreign Commerce, by a subcommittee thereof, under authority of H. Res. 441, Seventy-third Congress, conducted a petroleum investigation and on January 3, 1935, submitted to the House a report thereon (Report Numbered 2, Seventy-fourth Congress), which investigation and report served as the basis for the enactment of important oil legislation; and

Whereas on July 22, 1939, the President of the United States addressed a letter to the chairman of the Committee on Interstate and Foreign Commerce of the House, reading in part as follows:

"I appreciate the thoroughness with which the Committee on Interstate and Foreign Commerce conducted the petroleum investigation in 1934 in response to H. R. 441; but in the light of changes that have taken place, I believe the Committee may wish to study developments since that time by investigation and hearings prior to the next session of the Congress. To this end, and with a view to the enactment of suitable legislation in the next session, I request that the petroleum conservation bill which I today discussed with you and Representative Cole be introduced at this session;" and

Whereas the bill referred to by the President in such letter was introduced on July 26, 1939, as H. R. 7372: Therefore be it

*Resolved*, That the Committee on Interstate and Foreign Commerce, as a whole or by subcommittee, is authorized—

(a) To conduct such investigation as may be necessary to bring up to date its study and report made pursuant to H. Res. 441, Seventy-third Congress, which provided for the investigation of (1) the production, importation, storage, transportation, refining, purchase, and sale of petroleum and its products for the purpose of determining whether there is an excessive supply of petroleum and its products; whether such excessive supply, if it exists, injuriously affects commerce in petroleum and its products and has the effect of rendering unprofitable the operation of wells of small but settled production and will cause their natural resources, induced by absence of restrictions upon the quantity which may move in commerce, results in waste and inferior uses; whether restrictions should be placed upon the quantities of petroleum and its products which may move in commerce when an excessive supply exists, and, if so, whether such restrictions should regulate and coordinate commerce in petroleum and its products among the several States and with foreign nations, with fair and equitable apportionment among the States and among different operators and sources of supply; and whether commerce in petroleum and its products is of such a nature that it may be regarded as a unit for the purpose of establishing quotas irrespective of whether transactions are interstate or intrastate, or whether exportation or importation is involved; and (2) all other questions in relation to the subject of regulating commerce in petroleum and its products; and

(b) To investigate the methods and practices employed in the production and storage of petroleum from deposits within the United States, for the purpose of determining whether such methods and practices are wasteful of petroleum and the reservoir energy available for recovery thereof from such deposits; whether the employment of such methods and practices is inimical to the maintenance of reserves of petroleum, and of the facilities for the recovery and transportation thereof, available for military and supporting civilian needs in an adequate national defense; and whether the employment of such methods and practices burdens and obstructs interstate commerce and unduly limits the usefulness of instruments of transportation in, and causes the abandonment of facilities for, such commerce; and to investigate any other matters bearing upon the practicability and advisability of enacting legislation of the character of H. R. 7372, introduced on July 26, 1939; and

(c) To investigate methods and practices employed in the production, transportation, and distribution of petroleum and its products for the purpose of determining whether such methods and practices, in or in relation to interstate commerce in petroleum and its products, constitute unfair methods and practices from the standpoint of their effect upon producers and consumers.

The committee shall report to the House (or to the Clerk of the House if the House is not in session) during the present Congress the results of its investigation, together with such recommendations for legislation as it deems advisable.

For the purposes of this resolution the committee, or any subcommittee thereof, is authorized to sit and act during the present Congress at such times and places within the United States, whether or not the House is sitting, has recessed, or has adjourned, to hold such hearings, to require the attendance of such witnesses and the production of such books, papers, and documents, and to take such testimony, as it deems necessary. Subpenas shall be issued under the signature of the chairman of the committee or any member designated by him, and shall be served by any person designated by such chairman or member. The chairman of the committee or any member thereof may administer oaths to witnesses.

[H. R. 7372, 76th Cong., 1st sess.]

A BILL To promote the conservation of petroleum; to provide for cooperation with the States in preventing the waste of petroleum; to create an Office of Petroleum Conservation; to amend the Act of February 22, 1935, as amended, and for other purposes

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That this Act may be cited as the "Petroleum Conservation Act of 1939".

### FINDINGS AND DECLARATION OF POLICY

SEC. 2. (a) The Congress hereby finds that in the production and storage of petroleum from deposits situated within the United States, the employment of methods and practices which are wasteful of petroleum and of the reservoir energy available for the recovery thereof from such deposits (1) is inimical to the maintenance of reserves of petroleum, and of the facilities for the recovery and transportation thereof, available for military and supporting civilian needs in an adequate national defense; (2) burdens and obstructs interstate commerce and causes harmful diversion of such commerce; (3) if not controlled, will further and increasingly burden and obstruct interstate commerce and will unduly limit the usefulness of instruments of transportation in and cause the abandonment of facilities for such commerce; (4) causes interstate commerce to be the means of encouraging such wasteful methods and practices; and (5) constitutes an unfair method of competition in interstate commerce.

(b) It is hereby declared to be the policy of Congress, through the exercise in this Act of its power to provide for the maintenance of an adequate national defense and to regulate interstate commerce, to further the conservation of petroleum by the elimination of the wasteful methods and practices above referred to insofar as such methods and practices may be avoidable, and to encourage and assist the various States in their efforts to prevent the waste of petroleum.

### DEFINITIONS

SEC. 3. (a) When used in this Act, unless the context otherwise requires—

(1) The term "Secretary" means the Secretary of the Interior.

(2) The term "Commissioner" means the Commissioner of the Office of Petroleum Conservation, whose appointment is authorized in this Act, and shall be held to include, in addition, any associate commissioner, deputy commissioner, agent or agency designated by the Commissioner, with the approval of the Secretary, for the execution of any of the functions or powers vested in or transferred to the Commissioner under this Act.

(3) The term "petroleum" means any natural liquid or gaseous hydrocarbon mixture or compound.

(4) The term "crude oil" means any petroleum which occurs in the liquid state in a deposit and which reaches or would reach the surface in the liquid state.

(5) The term "natural gas" means any petroleum not defined as crude oil in paragraph (4).

(6) The term "deposit" means any natural underground reservoir containing a common accumulation of crude oil or natural gas, or both.

(7) The term "field" means any area, as outlined by the Commissioner for one or more of the purposes of this Act, which is or appears to be underlaid by one or more deposits, and shall include the natural underground reservoir or reservoirs of crude oil or natural gas, or both.

(8) The term "storage" means confinement in any tank, pit, artificial reservoir, or otherwise.

(9) The term "person" means an individual, a corporation, a partnership, a joint-stock company, a business trust, or an association.

(b) The Commissioner shall have power to define technical terms used in this Act insofar as such definitions are not inconsistent with the provisions of this Act.

## OFFICE OF PETROLEUM CONSERVATION

SEC. 4. (a) There is hereby established in the Department of the Interior an Office of Petroleum Conservation, which shall be under the direction of a commissioner. The Commissioner shall be appointed by the President, without regard to the civil-service laws but subject to the Classification Act of 1923, as amended. There shall be two associate commissioners appointed by the Secretary, subject to the civil-service laws and the Classification Act of 1923, as amended. The Secretary may, subject to the civil-service laws, appoint such deputy commissioners, experts, and other employees as he deems necessary to carry out the purposes of this Act and shall fix their compensation in accordance with the Classification Act of 1923, as amended. Attorneys appointed hereunder may appear for and represent the Commissioner in any litigation, but all such litigation shall be subject to the direction and control of the Attorney General.

(b) The Commissioner shall, under the direction and control of the Secretary, perform the functions vested in him by this Act, and the associate commissioners shall perform such functions as the Commissioner shall, with the approval of the Secretary, assign to them.

## INVESTIGATION OF PETROLEUM PRODUCTION

SEC. 5. (a) The Commissioner is authorized and empowered to investigate the conditions of petroleum production in all fields within the United States, including fields which may be discovered hereafter, to determine whether or not the methods and practices employed in the recovery of petroleum from deposits thereof, and in operations precedent thereto and attendant thereon, are effective in preventing the avoidable physical waste of crude oil and the avoidable waste of reservoir energy available for the recovery of crude oil. Such investigations shall be made in such sequence as may be feasible and from time to time as the Commissioner shall determine to be necessary.

(b) Within the meaning of subsection (a) of this section—

(1) Physical waste of crude oil shall be deemed to include the loss or destruction of crude oil after recovery thereof such as to prevent its application to useful purposes, and the entrapment or isolation of crude oil through irregular or premature encroachment of water, the loss or dissipation underground of crude oil or natural gas, and the premature release of natural gas fom solution in crude oil, all such as to render impracticable the recovery of such crude oil.

(2) Waste of reservoir energy shall be deemed to include the use or dissipation of such energy, either as gas energy, hydrostatic energy, or other natural energy, at any time at a rate or in a manner which would result in the exhaustion of the energy available for the recovery of crude oil prior to the recovery of the ultimate quantity of crude oil which such energy would be or might be made effective in recovering or rendering recoverable. Reservoir energy available for the recovery of crude oil shall be deemed to include that natural energy existent in any deposit containing crude oil in the recovery of which such energy may be made effective.

In making the determination required in subsection (a) of this section, the Commissioner shall consider, for each field as a whole and for the several parts thereof, such information as may be obtainable as to—

(1) porosity, permeability, and other characteristics of the deposit or deposits;

(2) the nature and character of the reservoir energy;

(3) well spacing, drilling practices, well casing and well completions;

(4) the rate of decline in reservoir pressure per unit of crude oil produced;

(5) the ratio of natural gas production to the amount of crude oil produced;

(6) the rate and manner of water encroachment within the productive formations;

(7) the ratio of production of crude oil to estimated reserves;

(8) the methods of well completion, presence of gas caps, and presence of gas-bearing zones open to any well;

(9) conditions of storage of crude oil recovered; and

(10) other characteristics and conditions of the source of supply and production therefrom.

### FINDINGS AND REGULATIONS

SEC. 6. (a) If, upon investigation of any field, the Commissioner shall find that the methods and practices then employed therein are effective in preventing avoidable waste, as waste is defined in subsection (b) of section 5 of this Act, and shall have no reason to believe that methods or practices which will result in avoidable waste are about to be employed therein, he shall issue his finding to that effect. The Commissioner shall make known such finding to the State agency charged with the regulation of petroleum development and production, or to the governor where there is no such agency, of the State or States wherein such field is situated, and shall cause such other publicity to be given such finding as he shall deem advisable. Such field shall be subject to subsequent similar investigation to be made at such time or times as the Commissioner shall deem necessary.

(b) If, upon investigation of any field, the Commissioner shall find that methods and practices employed therein, or which he shall have reason to believe are about to be employed therein, are not effective in preventing avoidable waste, as waste is defined in subsection (b) of section 5 of this Act, he shall issue his findings of fact, and shall by regulation designate and define with particularity those methods and practices which he shall find to be wasteful. The Commissioner shall make known his findings of fact to the State agency charged with the regulation of petroleum development and production, or to the governor where there is no such agency, of the State or States wherein such field is situated. In the promulgation of regulations under this section the Commissioner shall consider and make proper provision concerning, among others, the following factors of waste:

(1) The spacing, location, drilling, completion, or production of any well or wells so as to cause waste of reservoir energy.

(2) The loss by escape into the air or by wasteful burning of natural gas.

(3) The loss by evaporation, exposure, or wasteful burning of crude oil.

(4) The existence or creation of fire hazards.

(5) The drowning with water of any stratum capable of producing crude oil or natural gas, or both.

(6) The escape of crude oil from a productive formation through drainage, seepage, or uncontrolled migration.

(7) The premature release of natural gas from solution in crude oil.

(8) The operation of any well producing crude oil with an inefficient gas-oil ratio.

(9) The inefficient, excessive, or improper use of reservoir energy.

(10) The excessive production of natural gas alone or in conjunction with crude oil from a source of supply containing both even though such natural gas is used or transported for use in the generation of light, heat, or power, or for other purposes.

(11) The abandonment of any well in such manner as to render any crude oil unrecoverable or reservoir energy unavailable for the recovery of crude oil.

(c) In the investigation of the methods and practices employed in any field, the Commissioner shall consider the following, or any one of them, to be prima facie evidence of avoidable waste:

(1) The operation of any flowing well producing either crude oil or natural gas, or both, substantially at its open-flow capacity;

(2) The production of crude oil from any flowing well in any field at a rate which, in its relationship to the known crude-oil reserves of said well or field, is substantially in excess of the rate of production in relationship to reserves in other fields in which the Commissioner has found, under subsection (a) of section 6 of this Act, that the methods and practices therein employed are effective in preventing avoidable waste;

(3) Subsequent to one year after the effective date of this Act, the production of crude oil or natural gas, or both, from any field subject to investigation under this Act without the concurrent and reasonably accurate determination, by the producers in said field, of the factors listed in subsection (c) of section 5 of this Act as applied to said field.

### VOLUNTARY AGREEMENTS

SEC. 7. Upon the issuance of findings of fact under subsection (b) of section 6 of this Act, the Commission shall have power to consider any proposed voluntary agreements among the operators in such field designed to eliminate the avoidable waste found by the Commissioner to exist in such field. If the Commissioner determines that any such agreement or agreements will be effective in the elimination of such avoidable waste or any substantial part thereof, he shall approve such agreement or agreements and promulgate in addition thereto such regulations as provided in section 6 hereof as he shall deem necessary. If in the opinion of the Commissioner the failure or refusal of any operator or operators in a field voluntarily to join in any proposed agreement would impair the effectiveness thereof, he shall not approve such agreement in the event of nonjoinder by such operator or operators but shall promulgate regulations as provided in section 6 of this Act. If, at any time after the approval of any agreement under this section, the Commissioner shall find that such agreement is not effective in lieu of regulations, he shall in like manner promulgate such regulations and rescind his approval of such agreement.

### DEPOSITS ON LANDS OWNED BY THE UNITED STATES

SEC. 8. The provisions of this Act shall extend to all deposits owned by the United States, including unpatented deposits held under the mining laws, and deposits in tribal Indian lands and restricted individual Indian lands, and shall apply to all present and future production from the deposits above enumerated. The provisions of this section shall not be construed to modify or affect any provisions of existing law not inconsistent with the provisions of this Act. The functions vested in any other executive officer or agency, at the effective date of this Act, to prescribe the conditions of production or storage of petroleum within the scope of regulations authorized in this Act, together with the records, property (including office equipment), personnel, and unexpended balances of appropriations employed in and pertaining thereto, are hereby transferred to the Office of Petroleum Conservation.

### PROHIBITED PRACTICES

SEC. 9. It shall be unlawful for any person, during the effective period of any applicable regulation promulgated under the authority of section 6, section 7, or section 8 of this Act, to employ any method or practice designated and defined in such regulation as wasteful.

### RESEARCH AND EXPERIMENTATION; TRANSFER OF FUNCTIONS

SEC. 10. (a) The Commissioner shall (1) conduct such experimentation, investigation, or demonstration relating to the application of engineering, chemistry, or economics to the location, drilling, and completion of oil and gas wells in oil fields, the reserves of crude oil and associated natural gas, including comparative studies of domestic and foreign reserves, the uses of oil, the field uses of natural gas, and the production, refining, storage, transmission, and distribution of oil and its products and the liquid products of natural gas, and (2) compile, analyze, and publish such findings and data pertaining thereto, as the Secretary shall direct or approve. The Secretary shall transfer to the Office of Petroleum Conservation such of the foregoing functions as are now exercised or authorized to be exercised elsewhere in the Department of the Interior; and the President is authorized to transfer to said Office any of the foregoing functions now exercised or authorized to be exercised by any officer or agency not in said Department as he shall deem advisable.

(b) The Commissioner shall exercise such of the powers and perform such of the duties now vested in and imposed upon the Secretary in connection with the investigation, approval, alteration, and modification of cooperative or unit plans of development or operation of petroleum deposits as the Secretary shall designate.

(c) The functions vested in the Petroleum Conservation Division of the Department of the Interior, at the effective date of this Act, are hereby transferred to and vested in the Office of Petroleum Conservation.

(d) All functions vested in the President by the Act of February 22, 1935 (49 Stat. 30), as amended, except those under section 4 of said Act, are hereby transferred to and vested in the Office of Petroleum Conservation.

(e) Upon the transfer of any functions under this section, there shall be transferred to the Office of Petroleum Conservation the records, property (including office equipment), personnel, and unexpended balances of appropriations affected by such transfer. Such transfer shall not affect the classification or compensation of personnel so transferred: *Provided*, That such of the personnel transferred under this Act as do not already possess a civil-service status shall acquire such status (1) upon recommendation of the Secretary and (2) upon passing such suitable noncompetitive examinations as the Civil Service Commission shall prescribe.

### COOPERATION; JOINT ACTION

SEC. 11. (a) The Commissioner is authorized and empowered, in carrying out the functions vested in him by this Act, to cooperate with the executives, officials, and agencies of the several States, and with any agency or agencies acting pursuant to joint agreement between two or more States, and with educational and research institutions and organizations, public and private.

(b) The Commissioner is authorized, in conducting investigations and hearings in connection therewith, to conduct such investigations and hearings in whole or in part jointly with any duly authorized executive, official, or agency of any State, and with any agency or agencies acting pursuant to joint agreement between two or more States.

### PENALTIES

SEC. 12. (a) Any person who willfully violates any provision of this Act or any regulation promulgated under the authority contained in section 6, section 7, or section 8 of this Act, or who fails to obey any order of the Commissioner issued under the provisions of section 15 of this Act, shall, upon conviction, be fined not more than $1,000 for each day during which such violation or failure continues, or imprisoned not more than two years, or both.

(b) Any person who willfully resists, impedes, prevents, or interferes with the Commissioner or any of the employees or agents of the Office of Petroleum Conservation in the performance of duties pursuant to this Act, or who willfully and knowingly makes, or causes to be made, any statement in any report or document required to be filed under this Act or any rule or regulation thereunder, which statement is false or misleading as to any material fact, shall upon conviction be fined not more than $5,000 or imprisoned not more than one year, or both.

(c) Any person who, directly or indirectly, controls the acts or omissions of any person for which such person shall be liable under this section shall likewise be liable under this section to the extent that the acts or omissions of the controlled person constituting a violation were induced by such person.

(d) No prosecution for the collection or enforcement of any penalty under this section shall be deemed to be barred or terminated by reason of the expiration, subsequent to such violation, of the effective period of any regulation in respect of which such violation occurred.

### INVESTIGATIONS AND INJUNCTIONS

SEC. 13. (a) The Commissioner may, in his discretion, make such investigations as he deems necessary to determine whether any person has violated or is about to violate any provision of this Act or any regulations thereunder or is failing to comply with any order issued pursuant thereto, and may require or permit any person to file with him a statement in writing, under oath or otherwise as the Commissioner shall determine, as to any facts or circumstances concerning the matter to be investigated.

(b) Whenever it shall appear to the Commissioner that any person is engaged or about to engage in any acts or practices which constitute or will constitute a violation of the provisions of this Act or of any regulation thereunder, he may, in his discretion, bring an action in the proper district court of the United States or the United States District Court for the District of Columbia, to enjoin such acts or practices, and upon a proper showing a permanent or temporary injunction or restraining order shall be granted without bond.

(c) Upon appplication of the Commissioner, the district courts of the United States and the United States District Court for the District of Columbia shall have jurisdiction to issue writs of mandamus commanding any person to comply with the provisions of this Act or any regulation thereunder.

### JURISDICTION OF SUITS AND OFFENSES

SEC. 14. The district courts of the United States and the United States District Court for the District of Columbia shall have exclusive jurisdiction of violations of this Act or the regulations thereunder and of all actions at law and suits in equity brought to enforce any liability or duty created by, or to enjoin any violation of, this Act or the regulations thereunder. Any criminal proceeding may be brought in the district where any act or transaction constituting the violation occurred. Any action at law or suit in equity to enforce any liability or duty created by this Act or the regulations thereunder, or to enjoin any violation of this Act or any regulations thereunder, may be brought in any such district or in any district wherein the defendant is found or is an inhabitant or transacts business, and process in such cases may be served in any other district of which the defendant is an inhabitant or wherever the defendant may be found. Judgments and decrees so rendered shall be subject to review as provided in sections 128, 239, and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 225, 346, and 347).

SEC. 15. (a) Whenever the Commissioner shall have reason to believe that any person has violated or is violating the provisions of section 9 hereof, he shall have power to issue and cause to be served upon such person a written complaint stating the charges in that respect and containing a notice of a hearing before the Commissioner at a place therein fixed, on a date not less than five days after the service of such complaint. Any such complaint may be amended by the Commissioner at any time prior to the issuance of an order based thereon. The person complained of shall have the right to file an answer to the original or amended complaint, and to appear in person or by counsel and present evidence, under such regulations as the Commissioner shall prescribe. In the discretion of the Commissioner, any other person may be allowed to intervene in the proceeding and to appear in person or by counsel. In any such proceeding the rules of evidence prevailing in courts of law or equity shall not be controlling.

(b) If, after such hearing, the Commissioner shall find that the person has violated or is violating the provisions of section 9 of this Act, the Commissioner shall state in writing the findings as to the facts and shall issue and cause to be served on the person an order requiring such person to cease and desist from such violation and requiring the elimination of any waste resulting from such violation. The testimony taken at the hearing shall be reduced to writing and filed in the records of the Department of the Interior.

(c) Until a transcript of the record in a case has been filed in a court, as hereinafter provided, the Commissioner may, after reasonable opportunity to the operator to be heard, amend, or set aside the findings or order, in whole or in part.

(d) The Commissioner shall have power to petition any circuit court of appeals of the United States (including the Court of Appeals of the District of Columbia), or if all the circuit courts of appeals to which application may be made are in vacation, any district court of the United States (including the District Court of the United States for the District of Columbia), within any circuit or district, respectively, wherein any violation of the provisions of section 9 of this Act shall be found by the Commissioners to have occurred or wherein the person so found to have violated such provisions is found, resides, or transacts business, for the enforcement of such order and for appropriate temporary relief or restraining order, and shall certify and file in the court a transcript of the entire record in the proceeding, including the pleadings and testimony on which such order was entered and the findings and order of the Commissioner. No objection that has not been urged before the Commissioner shall be considered by the court, unless the failure or neglect to urge such objection shall be excused because of extraordinary circumstances. The findings of the Commissioner as to the facts, if supported by substantial evidence, shall be conclusive. If either party shall apply to the court for leave to adduce additional evidence, and shall show to the satisfaction of the court that such additional evidence is material and that there were reasonable grounds for failure to adduce such evidence in the hearing before the Commissioner, the court may order such additional evidence to be taken before the Commissioner and to be adduced at the hearing in such manner and upon such terms and conditions as the court may seem proper. The Commissioner may modify his findings as to the facts, by reason of the additional evidence so taken, and he shall file such modified or new findings, which, if supported by substantial evidence, shall be conclusive, and his recommendation, if any, for the modification or setting aside of the original order. The jurisdiction of the court shall be exclusive and its judgment and decree enforcing, modifying, or setting aside in whole or in part, any such order of the Commissioner shall be final, subject to review by the appropriate circuit court of appeals if application was made to the district court, and by the Supreme Court of the United States upon certiorari or certification as provided in sections 239 and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 346 and 347).

(e) Any person aggrieved by an order issued by the Commissioner in a proceeding to which such person is a party may obtain a review of such order in any circuit court of appeals of the United States in the circuit wherein the violation of the provisions of section 9 of this Act found by the Commissioner occurred or wherein such person resides or transacts business, or in the Court of Appeals of the District of Columbia, by filing in such court a written petition praying that the order of the Commissioner be modified or set aside. A copy of such petition shall be forthwith served upon the Commissioner, and thereupon the aggrieved party shall file in the court a transcript of the entire record in the proceeding, certified by the Commissioner, including the pleading and testimony on which the order was entered and the findings and order of the Commissioner. Upon such filing, the court shall proceed in the same manner as in the case of an application by the Commissioner under subsection (d) of this section, and shall have the same exclusive jurisdiction to grant to the Commissioner such temporary relief or restraining order as it deems just and proper, and in like manner to make and enter its judgment and decree enforcing, modifying, or setting aside in whole or in part the order of the Commissioner; and the findings of the Commissioner as to the facts, if supported by substantial evidence, shall in like manner be conclusive.

(f) The commencement of proceedings under subsection (d) or (e) of this section shall not, unless specifically ordered by the court, operate as a stay of the Commissioner's order.

(g) Petitions filed under this Act shall be heard expeditiously, and if possible within ten days after they have been docketed.

### POWERS IN INVESTIGATIONS AND HEARINGS

SEC. 16. The Commissioner may hold and conduct such hearings, investigations, and proceedings as may be necessary for the purposes of this Act, and for such purposes the provisions of subsections (b), (c), and (d) of section 21 of the Securities Exchange Act of 1934 relating to the administering of oaths and affirmations, and to the attendance and testimony of witnesses and the production of evidence (including penalties), shall apply. Hearings held in the course of and for the purpose of investigations authorized in subsection (a) of section 5 of this Act shall be held in the Federal judicial district in which the field under investigation, or any part thereof is situated.

### RULES AND REGULATIONS; ANNUAL REPORTS

SEC. 17. (a) The Commissioner shall have power to prescribe such rules as may be necessary for the execution of the functions vested in him by this Act, including but not limited to rules requiring the keeping of records and the submission of special and periodical reports, and providing for the inspection and examination of such records.

(b) The power to prescribe and promulgate rules and regulations contained in this Act shall include the power to alter, amend, modify, suspend the operation of, and rescind any such rules or regulations.

(c) Regulations promulgated under the authority of sections 6, 7, and 8 of this Act shall be published in the Federal Register and shall be subject to the provisions of the Federal Register Act, and shall be given such other publicity as the Commissioner shall determine and as the Secretary shall approve.

(d) The Secretary shall include in his annual reports to Congress such information, data, and recommendations for further legislation with respect to the subject matter of this Act as he shall deem advisable.

### COUNCIL ON PETROLEUM CONSERVATION

Sec. 18. (a) There is hereby established a Council on Petroleum Conservation, which shall consist of eighteen members, to be appointed by the Secretary, nine of whom shall be State officials engaged in the administration of petroleum-conservation laws, six of whom shall be engaged in the production of petroleum, and three of whom shall be engaged in the teaching of subjects related to petroleum at educational institutions. The Secretary shall call the first meeting of the council, at which meeting the council shall select one of its members to serve as chairman. The Commissioner shall designate an employee of the Office of Petroleum Conservation to serve as full-time secretary to the council and may furnish such other services as may be needed by the council. Members of the council shall be paid at the rate of $25 per diem while in attendance at and traveling to and from meetings of the council and necessary travel expenses.

(b) The council shall meet annually at such time and place as it shall determine, and at such annual meetings shall confer with representatives of the Federal Government on matters that may be laid before the meeting by members of the council and such representatives concerning the prevention of waste in petroleum production and the civilian and military petroleum needs of the Nation.

(c) The council shall arrange for and effect a current interchange of information between its members and the Office of Petroleum Conservation as to production methods and practices which will tend to effect the conservation of petroleum.

### PROHIBITION ON INTERSTATE SHIPMENT AND TRANSPORTATION; APPLICATION OF EXISTING LAW

Sec. 19. The shipment or transportation in interstate commerce from any State of crude oil or any product of crude oil which, or any part of which, was (1) produced in such State in violation of the laws thereof or of any regulation or order prescribed or issued pursuant to such laws, or (2) produced in such State in whole or in part by the employment of any method or practice declared in section 9 of this Act to be unlawful, is hereby prohibited. This section shall be administered and enforced under and in accordance with the provisions of the Act of February 22, 1935 (49 Stat. 30), as amended, including penalties, which Act is hereby made applicable to such crude oil and the products thereof.

### SEPARABILITY OF PROVISIONS

Sec. 20. If any provision of this Act, or the application of such provision to any person or circumstance, shall be held invalid, the remainder of the Act, and the application of such provision to persons or circumstances other than those as to which it is held invalid shall not be affected thereby.

### EFFECTIVE DATE

Sec. 21. This Act shall become effective on July 1, 1939.

Mr. Cole. As the resolution suggests that the committee bring up to date the investigation in 1934, the following will be printed in the order named:

First, House Resolution 441 of 1934, directing the initial investigation.

Next, report of the subcommittee to the House in response to that resolution, the report being dated January 3, 1935.

Next, the Connally Act and report of 1934.

Next, the interstate compact resolution as ratified in 1935.

Next, in 1935, H. R. 9053 and the report of the committee on that bill dated August 14, 1935.

The first extension of the Connally Act in June 1937 and the report of the committee accompanying the recommendation of that extension.

Next, the second extension of the Connally Act on June 29, 1939, with the report of the committee accompanying that recommendation.

Next, the second interstate compact and the report of the committee in 1937—July 27, 1937—recommending the enactment of the resolution.

The third extension of the interstate compact in 1939 with the report of the committee, June 30, 1939.

(The bills and reports above listed are in full as follows:)

[H. Res. 441, 73d Cong., 2d sess.]

RESOLUTION

*Resolved*, That the Committee on Interstate and Foreign Commerce, as a whole or by subcommittee, is authorized and directed to investigate (1) the production, importation, storage, transportation, refining, purchase, and sale of petroleum and its products for the purpose of determining whether there is an excessive supply of petroleum and its products; whether such excessive supply, if it exists, injuriously affects commerce in petroleum and its products and has the effect of rendering unprofitable the operation of wells of small but settled production and will cause their abandonment before the maximum economic yield is obtained; whether premature extraction of petroleum from natural resources, induced by absence of restrictions upon the quantity which may move in commerce, results in waste and inferior uses; whether restrictions should be placed upon the quantities of petroleum and its products which may move in commerce when an excessive supply exists, and, if so, whether such restrictions should regulate and coordinate commerce in petroleum and its products among the several States and with foreign nations, with fair and equitable apportionment among the States and among different operators and sources of supply; and whether commerce in petroleum and its products is of such a nature that it may be regarded as a unit for the purpose of establishing quotas irrespective of whether transactions are interstate or intrastate, or whether exportation or importation is involved; and (2) all other questions in relation to the subject of regulating commerce in petroleum and its products.

The committee shall report to the House (or to the Clerk of the House if the House is not in session) during present Congress the results of its investigation, together with such recommendations for legislation as it deems advisable.

For the purposes of this resolution the committee, or any subcommittee thereof, is authorized to sit and act during the present Congress at such times and places within the United States, whether or not the House is sitting, has recessed, or has adjourned, to hold such hearings, to require the attendance of such witnesses and the production of such books, papers, and documents, and to take such testimony, as it deems necessary. Subpenas shall be issued under the signature of the chairman of the committee or any member designated by him, and shall be served by any person designated by such chairman or member. The chairman of the committee or any member thereof may administer oaths to witnesses.

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[H. Rept. No. 2, 74th Cong., 1st sess.]

JANUARY 2, 1935.

Hon. SOUTH TRIMBLE,
*Clerk of the House of Representatives:*

On June 15, 1934, the House of Representatives adopted House Resolution No. 441, as follows:

"RESOLUTION

"*Resolved*, That the Committee on Interstate and Foreign Commerce, as a whole or by subcommittee, is authorized and directed to investigate (1) the production, importation, storage, transportation, refining, purchase, and sale of petroleum and its products for the purpose of determining whether there is an excessive supply of petroleum and its products; whether such excessive supply, if it exists, injuriously affects commerce in petroleum and its products and has the effect of rendering unprofitable the operation of wells of small but settled production and will cause their abandonment before the maximum economic yield is obtained; whether premature extraction of petroleum from natural resources, induced by absence of restrictions upon the quantity which may move in commerce, results in waste and inferior uses; whether restrictions should be placed upon the quantities of petroleum and its products which may move in commerce when an excessive supply exists, and, if so, whether such restrictions should regulate and coordinate commerce in petroleum and its products among the several States and with foreign nations, with fair and equitable apportionment among the States and among different operators and sources of supply; and whether commerce in petroleum and its products is of such nature that it may be regarded as a unit for the purpose of establishing quotas irrespective of whether transactions are interstate or intrastate, or whether exportation or importation is involved; and (2) all other questions in relation to the subject of regulating commerce in petroleum and its products.

"The committee shall report to the House (or to the Clerk of the House if the House is not in session) during the present Congress the results of its investigation, together with such recommendations for legislation as it deems advisable.

"For the purpose of this resolution the committee, or any subcommittee thereof, is authorized to sit and act during the present Congress at such times and places within the United States, whether or not the House is sitting, has recessed, or has adjourned, to hold such hearings, to require the attendance of such witnesses and the production of such books, papers, and documents, and to take such testimony, as it deems necessary. Subpenas shall be issued under the signature of the Chairman of the committee or any member designated by him, and shall be served by any person designated by such chairman or member. The chairman of the committee or any member thereof may administer oaths to witnesses."

The Chairman of the Committee on Interstate and Foreign Commerce of the House appointed the undersigned subcommittee to conduct the investigation authorized in the foregoing resolution.

Pursuant to the authority vested in the subcommittee, a report of its deliberations, findings, and recommendations is submitted herewith.

The subcommittee recognized that a thorough investigation of the petroleum industry should include not only consideration of the specific inquiries set forth in the foregoing resolution, but others definitely related thereto. Consequently, a study was made of the technical side of the problem—i. e., how the reserves of petroleum under the ground could be determined; where those resources were, and to what extent the quantity thereof could be accurately measured; the method of bringing this valuable natural resource to the surface; what happened to it thereafter; its movement through refining processes and all methods of transportation, ultimately reaching the great consuming public and making its contribution into practically every activity known to this age.

To give some idea of the many phases, technical and otherwise, of petroleum and its products, to which the subcommittee directed its attention, the following summary of the major subjects covered is given:

## Probable Supply of Petroleum and Products

### GEOLOGICAL SUMMARY

1. Geological concepts, tracing history of knowledge regarding occurrence of petroleum, including movement of production centers from East to South and Southwest.
2. Geological summary of Texas, Oklahoma, and California, with description of major fields in each State.
3. Geological summary of other States, with description of stripper well and minor flush areas.
4. Estimates of reserves in present proven areas, starting with earliest estimates and continuing to the present, with estimates from group of geologists. Method of calculation and probable accuracy.
5. Probable extent of oil supply which may be discovered in areas at present unproven, with estimates from geologists.

### TECHNOLOGICAL SUMMARY

1. How much oil is recovered and how has improved technology increased the recovery?
2. Changes in engineering views from the days when it was thought that oil flowed in underground rivers to the present concept of reservoir energy.
3. History of well-spacing and the relationship between well-spacing, energy utilization, and prevention of waste.
4. Methods of production and technical changes which have increased production, either through ability to drill deeper or recover larger proportion of oil.

### SUMMARY OF DEMAND

1. History of demand, with changes in characteristics and fundamental reasons for change.

2. Previous forecasts of demand.

3. Forecast of gasoline demand until 1950.

4. Forecast of probable crude-oil requirement to meet demand.

5. Forecast of probable changes in refining which will result. If, for example, gasoline demand by 1950 will double that of present, does this mean twice as much crude oil will be needed or will refineries of 1950 be able to produce twice as much motor fuel from crude as do the present plants? Hydrogenation and its economic status. Other substitutes.

6. Other demand factors, such as increasing efficiency of motors, habits of consumers, etc.

7. Probable future of oil burning, both domestic and industrial.

### IMPORTS AND EXPORTS

1. History of imports and exports.

(*a*) Development of foreign resources by American companies.

(*b*) Particular quality of imports, such as heavy crude for asphalt manufacture and fuel oil for ship-bunkering, with decrease in imports of gasoline-crudes and of gasoline.

(*c*) Analysis of reasons for decline in exports.

(*d*) Probable future trends in imports and exports.

### CRUDE-OIL PRODUCTION COSTS

1. A regional comparative study of total costs per barrel throughout the United States. Data by unit-areas in which costs are similar, due to similar geological structures, depths of producing sands, and age of fields, important factors in drilling and lifting costs.

2. Labor-cost per barrel, covering total United States production.

3. Analysis of all costs relating to the production of crude oil.

4. Operating costs in stripper areas in Kansas, Illinois, and Pennsylvania.

### INTERSTATE RELATIONSHIPS

1. Review of interstate or interregional movement of crude petroleum and products from 1920 to date.

2. Operations under the petroleum code.

3. Well abandonments.

4. Table showing approximate proportion of petroleum which is shipped from major States to other States.

5. Data showing interrelationship between intrastate and interstate shipments.

6. Methods for determining required crude-oil production and its equitable allocation between States.

The Honorable Harold L. Ickes, Secretary of the Interior and Administrator for the Petroleum Industry, placed at the disposal of the subcommittee such technical staff from the Bureau of Mines, and other departments of the Interior Department, as the subcommittee might require. We selected, as technical advisors, the following employees of the Federal Government:

E. B. Swanson, Chief of the Division of Production and Refining of the Petroleum Administrative Board.

Hale B. Soyster, Chief Oil and Gas Leasing Division of the United States Geological Survey.

W. S. Levings, geologist of the Petroleum Administrative Board.

Ben E. Lindsly, senior petroleum engineer of the Bureau of Mines, Bartlesville, Okla.

Harold C. Miller, senior petroleum engineer of the Bureau of Mines, San Francisco, Calif.

A. J. Kraemer, senior refinery engineer of the United States Bureau of Mines.

H. A. Breakey, economic analyst of the Bureau of Mines.

Dr. F. L. Carmichael, consulting statistician of the Petroleum Administrative Board.

Dr. Katharine Carman, connected with Petroleum Administrative Board.

Arthur H. Redfield, Acting Chief of the Petroleum Economics Division of the Bureau of Mines.

Dr. John W. Frey, Petroleum Administrative Board, marketing expert.

Kenneth L. Stone, chief accountant of the Petroleum Administrative Board on the subject of "Cost of Crude Oil Production."

These experts in the various fields assigned to them have worked continuously since the adjournment of Congress in preparing for our report what we consider to be the most illuminating and intelligent analysis of geology, production, refining, transportation, marketing, export, and import of petroleum and its products that has ever been compiled. The studies made by Dr. John W. Frye and Kenneth L. Stone were not completed in time to be incorporated as part of the record submitted by the subcommittee, but Mr. Stone's study is found in a printed pamphlet just issued by the Petroleum Administrative Board of the United States Department of the Interior, entitled "Preliminary Report on a Survey of Crude Petroleum, Cost of Production for the Years 1931–33, in Comparison with Years 1927–30," and they may be found in the office of the Superintendent of Documents, Government Printing Office. Dr. Frye's study will be available during the early part of the first session of the Seventy-fourth Congress, but in lieu thereof he submitted a statement found on page 2884 of the hearings.

Mr. David White, principal geologist, and a number of members of the Geological Survey associated in the General Land Office and Office of Indian Affairs assisted Mr. Soyster in the very able and complete work entitled "Geology and Occurrence of Petroleum in the United States," found in volume 2 of the hearings. The report of Harold C. Miller and Ben E. Lindsly on petroleum development and production and the report of A. J. Kraemer on effect of technologic facts on supply and demand of petroleum are found also in volume 2 of the hearings. The reports of the other members of the staff, working with the subcommittee, are found in volume 1.

To the technical staff assisting the subcommittee, and the assistants in the various Government departments who collaborated with them and with the members of the subcommittee from time to time, the subcommittee extends its sincere thanks.

During the interim between the adjournment of Congress and the formal taking of testimony, the subcommittee as a whole, or individual members thereof, visited the following principal oil-producing States: California, Colorado, Illinois, Indiana, Kansas, Michigan, New York, Ohio, Oklahoma, Pennsylvania, Texas, West Virginia, and Wyoming.

On these visits the subcommittee inspected many of the major fields and held informal conferences with men associated in various capacities with the petroleum industry, and also with the governing officials of some of the States.

After information had been acquired by the subcommittee, as a result of actual contact with the many practical operations of the petroleum industry and by consultation with the technical staff, the subcommittee conducted hearings during the week of September 17 in Washington. For the accommodation of witnesses in other parts of the country, the subcommittee, in addition to its sessions in Washington, conducted hearings in Oklahoma City, Okla.; Dallas, Tex.; and Los Angeles, Calif. Many witnesses were heard in person, and many contributions by letter and pamphlet were received. The hearings were closed with a total of 2,887 pages of printed matter, which includes the testimony of 136 witnesses and statistical data. The technical phases of the problem are found in the testimony of leading engineers and experts. The views of the leaders of the petroleum industry, whether associated with integrated or nonintegrated companies have been obtained. The attitude of the Federal Government has been presented by those responsible, to a large extent, for the administration of the petroleum industry either through the code, or otherwise. The governing officials of many of the important oil-producing States presented frank and helpful statements. It is a pleasure to state that in not one single instance was it necessary to subpena anyone before the subcommittee.

A thorough and detailed index of all testimony taken by the subcommittee has been compiled and is printed and bound in volume 5 of the hearings. It provides a ready reference to every subject considered by and discussed before the subcommittee. In view of the very exhaustive analysis of the testimony, the subcommittee has not thought it necessary to include herein a detailed summary of all the evidence.

When it is realized how imperative and absolutely essential petroleum and its products are to the Nation, not only in war times but in peace times as well, any threatened or possible exhaustion of such a resource is of serious consequence.

Petroleum is admittedly irreplaceable. The quantity of petroleum in known fields and pools is capable of fairly accurate determination. With the quantity of known reserves established and the discoveries in the future entirely problematical, it is natural that the conservation of this very valuable resource has claimed the attention of the Federal and State Governments as well as of the petroleum industry for some time.

During the war the importance of our petroleum resources was brought more forcibly to the attention of the country as a whole than ever before. In December 1924, President Coolidge authorized the formation of the Federal Conservation Board, consisting of the Secretaries of War, Navy, Interior, and Commerce. In doing so President Coolidge stated:

"The future might be left to the simple workings of the law of supply and demand, but for the patent fact that the oil industry's welfare is so intimately linked with the industrial prosperity and safety of the whole people, that Government and business can well join forces to work out this problem of practical conservation."

The Federal Oil Conservation Board submitted five interesting and able reports, the last in 1932. The hearings before the Board and the reports of the Board are public documents and we commend all of them to the Members of Congress. The concern expressed by President Coolidge has been reiterated in one form or another by each succeeding President. In the early part of the present administration, President Roosevelt addressed the following letter to the Honorable John N. Garner, President of the Senate, and the Honorable Henry T. Rainey, Speaker of the House:

"As the Congress is doubtless aware, a serious situation confronts the oil-producing industry. Because oil taken from the ground is a natural resource which once used cannot be replaced, it is of interest to the Nation that its production should be under reasonable control for the best interests of the present and future generations.

"My administration for many weeks has been in conference with the Governors of the oil-producing States and with component parts of the industry, but it seems difficult, if not impossible, to bring order out of chaos only by State action. In fact, this is recognized by most of the Governors concerned.

"There is a wide-spread demand for Federal legislation. May I request that this subject be given immediate attention by the appropriate committee or committees. The Secretary of the Interior stands ready to present any information or data desired.

"May I suggest further that in order to save the time of the special session it might be possible to incorporate action relating to the oil industry with whatever action the Congress decides to take in regard to other industries—in other words, that consideration could be given at the same time that action is taken on bills already introduced and now pending in the committee."

With the passage of the National Industrial Recovery Act, the oil industry like other industries, was placed under a code. Special sections dealing with the importation of petroleum and its products were included. Another special section made provision for the exact type of regulation to be imposed on that industry. This special section known as "section 9 (C)," or the "Connally amendment," is as follows:

"The President is authorized to prohibit the transportation in interstate and foreign commerce of petroleum and the products thereof produced or withdrawn from storage in excess of the amount permitted to be produced or withdrawn from storage by any State law or valid regulation or order prescribed thereunder, by any board, commission, officer, or other authorized agency of a State. Any violation of any order of the President issued under the provisions of this subsection shall be punishable by fine of not to exceed $1,000 or imprisonment for not to exceed 6 months, or both."

The Secretary of the Interior was designated as Oil Administrator and the Petroleum Administrative Board was created with extremely important duties.

Since the enactment of the National Industrial Recovery Act, and the adoption of the Petroleum Code thereunder, there has been much litigation with respect thereto in State and Federal courts. The principal cases which present constitutional questions and which the subcommittee deems of vital importance are the Amazon and the Panama cases initiated in the State of Texas and argued on

December 10, 1934, before the Supreme Court of the United States. The importance of the decision in these cases, which is expected to be delivered at an early date, is discussed later in this report.

For many years conservation of petroleum resources has been of very definite concern to the oil-producing States, resulting in waste and proration statutes being passed and in effect today. Many of these statutes provide for the separate agencies with broad authority. In addition to the interest of the Federal Government and that of the oil-producing State governments, studies and recommendations have been made by the various groups within the industry.

The Federal Oil Conservation Board, reporting finally in 1932, recommended that the producers of petroleum be relieved of Federal antitrust legislation, to aid in voluntary cooperation in endeavors to limit production of crude oil in the United States. The committee on mineral law of the American Bar Association has considered the practical and constitutional problems involved. Various solutions to these problems were proposed. Interstate compacts for the regulation of the production of petroleum, with the principal oil-producing States as contracting parties were suggested, as was actual regulation of the business by the Federal Government. A proposed Federal law drafted to effect such an end was included. Two bills, one to provide for voluntary unit development or cooperation voluntarily among all the owners of an oil field for its most economic operation by a Federal law lessening the restraints of the antitrust laws, and the others to provide for compulsory unit development proposed for enactment by State legislatures, were submitted.

The American Institute of Mining and Metallurgical Engineers reported the addresses of many prominent authorities favoring some form of restraint on the wide open competitive methods, and also discussions by Roscoe Pound, dean of the Law School of Harvard University, and by Henry M. Bates, dean of the Law School of the University of Michigan, dealing with certain legal questions. In 1925 a report of a committee of 11 to the American Petroleum Institute on the subject "American Petroleum—Supply and Demand" was made. This survey purported in its own language to be thorough and country wide, and it incorporated the opinions and findings of experts and scientists in the industry and in related fields. Frequent reference to this report is found in the hearings.

The Planning and Coordination Committee of the Petroleum Industry under the code has been very active from the time of its organization. Representatives of this group have appeared frequently before the subcommittee. Judge Amos L. Beaty, chairman of the Planning and Coordination Committee, testified and later presented a brief in support of legislation which he favored (p. 2839). On December 19, 1934, the subcommittee received a letter from the Planning and Coordination Committee enclosing a draft of a bill which it recommends. This letter did not reach the subcommittee in time to be printed as part of the hearings.

The American Petroleum Institute, an active organization consisting of representatives of integrated an nonintegrated companies, met in Dallas, Tex., on November 12 to 15, inclusive. At this session majority and minority reports recoommending concrete legislation were presented. Testimony before the subcommittee explaining the attitude of the American Petroleum Institute is found in many places in the hearings. The personnel of the board of directors of the American Petroleum Institute, a copy of the majority and minority reports, and the division of vote by the board of directors, are found in the hearings at pages 1754 to 1759.

At various times the Governors of the oil-producing States have attempted to solve the major problems through the medium of interstate compacts. In 1931 a compact between some of the States was agreed upon but was later declared illegal. Proposed Federal legislation to permit such compacts was considered by a committe of the Seventy-second Congress. On December 3, 1934, a meeting was held at the home of Governor-elect E. W. Marland, in Ponca City, Okla., for for the purpose of discussing the possibility of an interstate compact. That meeting adjourned to January 3, 1935. The resolutions presented by the Governors and Governors-elect of the oil-producing States attending the meeting are found in the record compiled by the subcommittee (p. 2884).

Hearings on H. R. 9676, and S. 3495, known as the Disney bill and the Thomas bill respectively, were held in the second session of the Seventy-third Congress. Section 1 of H. R. 9676, which is a statement of policy, was used as a basis for the resolution under which the subcommittee has functioned.

The Secretary of the Interior, Hon. Harold L. Ickes, in an address delivered at the meeting of the American Petroleum Institute in Dallas, in November last, discussed the question of making the petroleum industry a public utility, and the chief executive of one of the leading companies in the industry, in a statement before the subcommittee, discussed the question of the nationalization of the industry. The subcommittee, however, has not had the time to go into either one of these subjects and expresses no opinion thereon at this time.

It is evident from the aforegoing brief summation of Federal, State, and other activities manifesting concern as to our petroleum resources and interest in the conservation thereof, that the subject is of unusual importance. The subcommittee is of opinion that the hearings filed herewith, along with the available data from sources hereinbefore mentioned and many others, present a wealth of information for the consideration of Congress in dealing with the many subjects incident to petroleum legislation.

We have not deemed it advisable at this time to set forth in this report or to prepare for introduction when Congress convenes on January 3, a bill or bills embodying our conception of what permanent and/or temporary legislation should be enacted by the Seventy-fourth Congress dealing with the petroleum industry. There are numerous reasons for our taking this position. In the first place the National Industrial Recovery Act, though temporary, has through its provisions, and rules and regulations passed thereunder, helped the petroleum industry to some extent. At this time, for instance, the operation of the Federal Tender Board is given a great deal of credit for production being fairly in line with the demand established by the Federal Government. We anticipate that some of the pending temporary legislation will become permanent. Because of the constitutional difficulties which have arisen in the last 18 months in the administration of the petroleum code and other provisions of the National Industrial Recovery Act pertaining to petroleum, we feel that the decision by the Supreme Court of the United States in the Amazon and Panama cases should be very helpful to Congress in drafting legislation. The National Resources Board appointed by President Roosevelt early last summer to make a study of national, including natural resources, has just submitted an exhaustive report, volume 1, thereof being the only one available to the subcommittee at this time. Volume 5 evidently will deal with our natural resources and it is important that the information and recommendations therein be known to Congress before definite legislation is considered.

Another reason for not submitting legislation with this report is the pending effort of the Governors of the oil-producing States to effect an interstate compact. We have made reference to the first meeting of the Governors' conference on December 3 last. A second meeting will be held simultaneously with the convening of the Seventy-fourth Congress. We strongly urge upon the oil-producing States the adoption of State compacts to deal with the problems of the production of petroleum with which individual States are powerless to cope. The subcommittee clearly recognizes the principle of State compacts for the purpose of effecting a common end of State interests. Other plans for dealing with the problems of petroleum production outside of State lines are full of constitutional questions. State compacts, flexible in operation and over which the President of the United States or a Federal agency in the interest of the consuming masses of the Nation, may hold some veto power, is a solution of those problems of petroleum production, which cannot be solved by modification of the "law of capture" and other legislation operating within State boundaries. We are confident that the Governors of the oil-producing States and the majority of the industry within those States, are cognizant of the common-sense theory that waste of petroleum resources must be prevented. Huge waste, such as the subcommittee has witnessed in the Panhandle of West Texas should not be permitted to continue. Waste of many kinds in other fields, both past and present, shock anyone possessing familiarity therewith.

At the meeting of the Governors and Governors-elect and representatives of Governors, held on December 3, various important resolutions looking to the formation of an interstate compact were offered. It is the understanding of the subcommittee that these resolutions will be before the second meeting on January 3, 1935. This discussion and consideration by the Governors of our oil-producing States coming at this time when the legislatures of all of these States are either in session or about to convene, presents ample opportunity for the oil-producing States through actual agreement and approval to present to the Seventy-fourth Congress before its adjournment, a definite, specific compact for its consideration. It will not take many weeks after January 3 for the Congress, to decide whether the effort of the Governors of the oil-producing States promises worth-while results. We believe they should be given the opportunity to take the initiative in drafting definite proposals without the Congress setting forth in a permissive way something in advance for the States to adopt. Something real and substantial may grow out of the pending effort.

If it does not the Seventy-fourth Congress will have ample time to pass such legislation as may be necessary.

The determination of the necessity, extent, and character of possible legislation, depends in part upon the question of whether an excessive supply of petroleum exists. There may be a difference of opinion as to whether "excessive supply" of petroleum and its products means supply available to meet current demand, or reserves available to meet future demand.

An excessive supply of petroleum and its products to meet current demand undoubtedly exists. The potential production, based upon available potentials, is considerably in excess of today's production of crude oil. Large quantities of crude oil are above the ground in storage and imports of crude oil have been limited by definite restrictions. The total demand for crude oil, which includes domestic consumer demand and export requirements, is much less than the aggregate of potential production, stocks in storage, and supplies available in foreign countries. There can be no doubt of the capability of the major oil fields to produce oil currently in excess of the rate at which the Nation can consume petroleum and its products. This being true, an admittedly excessive supply will exist to meet current demand so long as proven reserves are capable of production in excess thereof.

Based upon conservative estimate of known reserves, an excessive supply of petroleum to meet future demand does ont exist. Numerous estimates of the petroleum resources of the United States have been made during the past quarter century. Should future daily demand continue approximately in the amount required today, and no additional discoveries of new fields be made, the present known reserves would last—according to most estimates—approximately 15 years.

This conclusion is reached upon the basis of present-day production methods and ignores the possibility of future discoveries. We feel, however, that new pools will undoubtedly be found in many parts of the country and improved methods of bringing the oil to the surface, or even mining for the same—where too great a depth does not exist—will all result in a greater ultimate recovery. Oil shale, coal, and other substitutes provide, at increased cost, vast quantities of petroleum products. The life of the present reserves to meet our future demands may be extended beyond the time estimated, by improved mechanical devices for the use of petroleum products. We do not feel justified, however, even in view of the admitted possibility of improved methods of recovery being employed, and of additional discoveries of new pools, and of the use of substitutes and of possible improved mechanical devices, in arriving at the conclusion that the petroleum reserves available in the country today to meet future demand are excessive, but, on the contrary, we feel that they are of a very limited nature.

Statistics of production are also statistics of exhaustion. No one knows how much petroleum there is underground in America. We take the broad position that whether our petroleum supplies are large or small, they should not be physically wasted above or below the ground. Cheap and abundant fuel and power are the very cornerstone of American industry, transportation, and business. The people who predict abundant petroleum reserves 50 or 100 years from now, do not give bond for the accuracy of their estimates. We recommend, not only to the National Congress but to the State legislatures of the oil-producing States, as well as to public opinion itself, the strengthening of existing legislation toward the prevention of waste. The United States Government, with respect to petroleum on public and Indian lands, has not been without fault in this matter. As owners of public lands and guardians of Indian lands, the National Government has itself been a party to the rapid extraction of petroleum and the exhaustion of reservoir energy. We are impressed, despite much constructive legislation by many of the States, there is still room for much more to be done.

The subcommittee has observed and had experience with the Petroleum Administrative Board as now constituted. While it is our belief that the Secretary of the Interior and the Petroleum Administrative Board have worked to accomplish worth-while results, we do not believe that such an agency of the Federal Government, dealing with the important problem before it, should be continued as a permanent agency in its present form.

The petroleum industry, the third largest in the country, represents an investment, based upon present-day values, of more than $12,000,000,000. No argument is needed to establish reasons for the interest of the National Government in the future development and in the operations of many of the present-day activities in the petroleum industry.

We recommend, therefore, that any legislation establishing permanently the interest of the Federal Government in the petroleum industry should provide for an agency, commission, or board, as it might be designated, to absorb some of the activities in various departments of the Federal Government as now constituted. The Bureau of Mines might very easily be revamped for the purpose.

The subcommittee feels that such an agency should have sufficient personnel and authority to study continuously the status of the petroleum reserves; encourage discoveries of new pools; assist in improving present-day methods of production; study the possibility and expense of repressuring in various existing fields; systematically determine the total demand for petroleum and its products, both domestic and foreign; have jurisdiction over the management of oil-producing public and Indian lands; be given jurisdiction to establish pipe-line rates, unless the Interstate Commerce Commission is given greater appropriation to handle more expeditiously this subject now before it; and to study and make report as to the advisability of divorcing pipe lines; recommend at regular intervals to the President of the United States—the President being given authority by Congress to approve—limitations upon the importation of petroleum and its products, including natural asphalt, so as to prevent importation thereof from interfering with current domestic production by supplying an undue proportion of the domestic consumption and export demand therefor; to represent the Federal Government, if need be, in any cooperative interstate compact, agreed upon and approved by the Congress; and in general, to possess all other necessary authority so as to present that dignity, from a national standpoint, to which the subcommittee believes the petroleum industry is entitled.

Coal, timber, and other natural resources, might properly also be included under the jurisdiction of this agency.

We are convinced that not sufficient attention is being paid to the interest of consumers of petroleum products. Settlements of so-called price wars, which result in some cases in an increase of 100 percent in the cost of gasoline, strain the credulity of the observer on the theory that they just happened without prearrangement in view of the fact that the Sherman Antitrust Act is still the law of the land, except insofar as temporarily it may be suspended by the operation of the National Industrial Recovery Act, we think that the fixing of gasoline prices is a matter worthy of close and constant scrutiny by the Department of Justice.

It is the purpose of the members of this subcommittee, all of whom have been reelected to the Seventy-fourth Congress, to ask the permission of the Seventy-fourth Congress to file a supplemental report when the decision of the Supreme Court in the Panama and Amazon cases shall have been rendered, the result of the Governors' conference, now in session with respect to an interstate compact, shall have been concluded, and the full report of the National Resources Board shall have been published.

We present this report with an acknowledgment of our real gratitude for the opportunity afforded us to become acquainted with one of the most fascinating and important subjects before the country today.

The entire appropriation placed at our disposal in conducting this investigation has not been used and approximately $5,000 thereof will remain in the contingent fund of the House.

Respectfully submitted.

William P. Cole, Jr., *Chairman.*
Samuel B. Pettengill.
Edward A. Kelly.
Carl E. Mapes.
Chas. A. Wolverton.

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[Public—No. 14—74th Congress]

[S. 1190]

AN ACT To regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That it is hereby declared to be the policy of Congress to protect interstate and foreign commerce from the diversion and obstruction of, and the burden and harmful effect upon, such commerce caused by contraband oil as herein defined, and to encourage the conservation of deposits of crude oil situated within the United States.

SEC. 2. As used in this Act—

(1) The term "contraband oil" means petroleum which, or any constituent part of which, was produced, transported, or withdrawn from storage in excess of the amounts permitted to be produced, transported, or withdrawn from storage under the laws of a State or under any regulation or order prescribed thereunder by any board, commission, officer, or other duly authorized agency of such State, or any of the products of such petroleum.

(2) The term "products" or "petroleum products" includes any article produced or derived in whole or in part from petroleum or any product thereof by refining, processing, manufacturing, or otherwise.

(3) The term "interstate commerce" means commerce between any point in a State and any point outside thereof, or between points within the same State but through any place outside thereof, or from any place in the United States to a foreign country, but only insofar as such commerce takes place within the United States.

(4) The term "person" includes an individual, partnership, corporation, or joint-stock company.

SEC. 3. The shipment or transportation in interstate commerce from any State of contraband oil produced in such State is hereby prohibited. For the purposes of this section, contraband oil shall not be deemed to have been produced in a State if none of the petroleum constituting such contraband oil, or from which it was produced or derived, was produced, transported, or withdrawn from storage in excess of the amounts permitted to be produced, transported, or withdrawn from storage under the laws of such State or under any regulation or order prescribed thereunder by any board, commission, officer, or other duly authorized agency of such State.

SEC. 4. Whenever the President finds that the amount of petroleum and petroleum products moving in interstate commerce is so limited as to be the cause, in whole or in part, of a lack of parity between supply (including imports and reasonable withdrawals from storage) and consumptive demand (including exports and reasonable additions to storage) resulting in an undue burden on or restriction of interstate commerce in petroleum and petroleum products, he shall by proclamation declare such finding, and thereupon the provisions of section 3 shall be inoperative until such time as the President shall find and by proclamation declare that the conditions which gave rise to the suspension of the operation of the provisions of such section no longer exist. If any provision of this section or the application thereof shall be held to be invalid, the validity or application of section 3 shall not be affected thereby.

SEC. 5. (a) The President shall prescribe such regulations as he finds necessary or appropriate for the enforcement of the provisions of this Act, including but not limited to regulations requiring reports, maps, affidavits, and other documents relating to the production, storage, refining, processing, transporting, or handling of petroleum and petroleum products, and providing for the keeping of books and records, and for the inspection of such books and records and of properties and facilities.

(b) Whenever the President finds it necessary or appropriate for the enforcement of the provisions of this Act, he shall require certificates of clearance for petroleum and petroleum products moving or to be moved in interstate commerce from any particular area, and shall establish a board or boards for the issuance of such certificates. A certificate of clearance shall be issued by a board so established in any case where such board determines that the petroleum or petroleum products in question does not constitute contraband oil. Denial of any such certificate shall be by order of the board, and only after reasonable opportunity for hearing. Whenever a certificate of clearance is required for any area in any State, it shall be unlawful to ship or transport petroleum or petroleum products in interstate commerce from such area unless a certificate has been obtained therefor.

(c) Any person whose application for a certificate of clearance is denied may obtain a review of the order denying such application in the United States District Court for the district wherein the board is sitting by filing in such court within thirty days after the entry of such order a written petition praying that the order of the board be modified or set aside, in whole or in part. A copy of such petition shall be forthwith served upon the board, and thereupon the board shall certify and file in the court a transcript of the record upon which the order complained of was entered. Upon the filing of such transcript, such court shall have jurisdiction to affirm, modify, or set aside such order, in whole or in part.

No objection to the order of the board shall be considered by the court unless such objection shall have been urged before the board. The finding of the board as to the facts, if supported by evidence, shall be conclusive. The judgment and decree of the court shall be final, subject to review as provided in sections 128 and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 225 and 347).

Sec. 6. Any person knowingly violating any provision of this Act or any regulation prescribed thereunder shall upon conviction be punished by a fine of not to exceed $2,000 or by imprisonment for not to exceed six months, or by both such fine and imprisonment.

Sec. 7. (a) Contraband oil shipped or transported in interstate commerce in violation of the provisions of this Act shall be liable to be proceeded against in any district court of the United States within the jurisdiction of which the same may be found, and seized for forfeiture to the United States by a process of libel for condemnation; but in any such case the court may in its discretion, and under such terms and conditions as it shall prescribe, order the return of such contraband oil to the owner thereof where undue hardship would result from such forfeiture. The proceedings in such cases shall conform as nearly as may be to proceedings in rem in admiralty, except that either party may demand a trial by jury of any issue of fact joined in any such case, and all such proceedings shall be at the suit of and in the name of the United States. Contraband oil forfeited to the United States as provided in this section shall be used or disposed of pursuant to such rules and regulations as the President shall prescribe.

(b) No such forfeiture shall be made in the case of contraband oil owned by any person (other than a person shipping such contraband oil in violation of the provisions of this Act) who has with respect to such contraband oil a certificate of clearance which on its face appears to be valid and to have been issued by a board created under authority of section 5, certifying that the shipment in question is not contraband oil, and such person had no reasonable ground for believing such certificate to be invalid or to have been issued as a result of fraud or misrepresentation of fact.

Sec. 8. No common carrier who shall refuse to accept petroleum or petroleum products from any area in which certificates of clearance are required under authority of this Act, by reason of the failure of the shipper to deliver such a certificate to such carrier, or who shall refuse to accept any petroleum or petroleum products when having reasonable ground for believing that such petroleum or petroleum products constitute contraband oil, shall be liable on account of such refusal for any penalties or damages. No common carrier shall be subject to any penalty under section 6 in any case where (1) such carrier has a certificate of clearance which on its face appears to be valid and to have been issued by a board created under authority of section 5, certifying that the shipment in question is not contraband oil, and such carrier had no reasonable ground for believing such certificate to be invalid or to have been issued as a result of fraud or misrepresentation of fact, or (2) such carrier, as respects any shipment originating in any area where certificates of clearance are not required under authority of this Act, had no reasonable ground for believing such petroleum or petroleum products to constitute contraband oil.

Sec. 9. (a) Any board established under authority of section 5, and any agency designated under authority of section 11, may hold and conduct such hearings, investigations, and proceedings as may be necessary for the purposes of this Act, and for such purposes those provisions of section 21 of the Securities Exchange Act of 1934 relating to the administering of oaths and affirmations, and to the attendance and testimony of witnesses and the production of evidence (including penalties), shall apply.

(b) The members of any board established under authority of section 5 shall be appointed by the President, without regard to the civil service laws but subject to the Classification Act of 1923, as amended; and any such board may appoint, without regard to the civil service laws but subject to the Classification Act of 1923, as amended, such employees as may be necessary for the execution of its functions under this Act.

Sec. 10. (a) Upon application of the President, by the Attorney General, the United States District Courts shall have jurisdiction to issue mandatory injunctions commanding any person to comply with the provisions of this Act or any regulation issued thereunder.

(b) Whenever it shall appear to the President that any person is engaged or about to engage in any acts or practices that constitute or will constitute a violation of any provision of this Act or of any regulation thereunder, he may in his discretion, by the Attorney General, bring an action in the proper United States District Court to enjoin such acts or practices, and upon a proper showing a permanent or temporary injunction or restraining order shall be granted without bond.

(c) The United States District Courts shall have exclusive jurisdiction of violations of this Act or the regulations thereunder, and of all suits in equity and actions at law brought to enforce any liability or duty created by, or to enjoin any violation of, this Act or the regulations thereunder. Any criminal proceeding may be brought in the district wherein any act or transaction constituting the violation occurred. Any suit or action to enforce any liability or duty created by this Act or regulations thereunder, or to enjoin any violation of this Act or any regulations thereunder, may be brought in any such district or in the district wherein the defendant is found or is an inhabitant or transacts business, and process in such cases may be served in any other district of which the defendant is an inhabitant or wherever the defendant may be found. Judgments and decrees so rendered shall be subject to review as provided in sections 128 and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 225 and 347).

SEC. 11. Wherever reference is made in this Act to the President such reference shall be held to include, in addition to the President, any agency, officer, or employee who may be designated by the President for the execution of any of the powers and functions vested in the President under this Act.

SEC. 12. If any provision of this Act, or the application thereof to any person or circumstance, shall be held invalid, the validity of the remainder of the Act and the application of such provision to other persons or circumstances shall not be affected thereby.

SEC. 13. This Act shall cease to be in effect on June 16, 1937.

Approved, February 22, 1935.

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[H. Rept. No. 148, 74th Cong., 1st sess.]

The Committee on Interstate and Foreign Commerce, to whom was referred the bill (S. 1190) to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes, having considered and amended the same, report thereon with a recommendation that it pass.

The committee amendment strikes out all of the Senate bill and inserts in lieu thereof a substitute.

S. 1190, introduced by Senator Connally, of Texas, passed the Senate on January 21, 1935. The report accompanying this bill in the Senate contained the following introductory statement:

"S. 1190 is a substantial but somewhat elaborated reenactment of section 9 (c) of the National Industrial Recovery Act relating to the interstate shipment of petroleum and the liquid products, derivatives, and blends of crude petroleum, any part of which was produced, refined, processed, transported, withdrawn from storage, or otherwise handled in violation of any State law or valid orders, rules, or regulations prescribed thereunder.

"When the National Industrial Recovery Act was enacted it contained section 9 (c), which read as follows:

"'The President is authorized to prohibit the transportation in interstate and foreign commerce of petroleum and the products thereof produced or withdrawn from storage in excess of the amount permitted to be produced or withdrawn from storage by any State law or valid regulation or order prescribed thereunder, by any board, commission, officer, or other duly authorized agency of a State. Any violation of any order of the President issued under the provisions of this subsection shall be punishable by fine of not to exceed $1,000, or imprisonment for not to exceed six months, or both.'"

This bill was referred to the Committee on Interstate and Foreign Commerce of the House on January 23, 1935, and shortly thereafter was referred to a subcommittee. After very serious consideration in several executive sessions the subcommittee reported the bill back to the entire committee on February 6, 1935, said report reading as follows:

HON. SAM RAYBURN,
*Chairman, Committee on Interstate and Foreign Commerce,*
*House of Representatives, Washington, D. C.*

DEAR MR. RAYBURN: S. 1190, introduced by Senator Connally, having passed the Senate and referred to your committee, was in turn referred by you to the undersigned special subcommittee, designated to consider legislation pertaining to petroleum.

The subcommittee has given very serious consideration to this bill in a number of executive sessions. This subcommittee happens to be the same subcommittee as the personnel that was appointed by you in the Seventy-third Congress, under House Resolution No. 441.

In the report of that subcommittee, following a lengthy investigation, we had the following to say:

"It is the purpose of the members of this subcommittee, all of whom have been reelected to the Seventy-fourth Congress, to ask permission of the Seventy-fourth Congress to file a supplemental report when the decision of the Supreme Court in the Panama and Amazon cases shall have been rendered, the result of the governors' conference, now in session with respect to an interstate compact, shall have been concluded, and the full report of the National Resources Board shall have been published."

The decision of the Supreme Court in the Panama and Amazon cases having been rendered and the report of the National Resources Board on file, two of the reasons assigned for delay in making a final report no longer exist. The remaining reason, the result of the governors' conference then in session with respect to an interstate compact, still remains. Since the meeting of the representatives of the eight principal oil-producing States on January 3, 1935, action by the Legislatures of the States of California, New Mexico, Oklahoma, and Texas, in the form of legislation authorizing the Governors of the respective States, or their designated representatives, to participate in a conference for the purpose of effecting an interstate compact, have been passed. A meeting for this purpose of the Governors or their representatives acting upon legislation authorizing action has been called for February 15 and 16 in Dallas, Tex. What will be accomplished at that meeting on February 15 and 16, we, of course, do not know, but until the Governors of the oil-producing States have had a reasonable time to demonstrate, what, if anything, they can do toward a solution of even a part of the petroleum problem before us, the subcommittee does not feel that anything that might be considered as a final report by them shall be made.

The Connally bill (S. 1190) does not represent the views of the subcommittee but, in view of your urgent request, the subcommittee reports the same back to the full committee for whatever action it sees fit to take, with the understanding that each member of the subcommittee will feel at liberty to express his individual views before the full committee during consideration of the bill.

Very sincerely yours,

William P. Cole, Jr., *Chairman.*
Samuel B. Pettengill.
Edward A. Kelly.
Charles A. Wolverton.
Carl E. Mapes.

With the opinions of the Supreme Court in the Amazon case and the great amount of testimony taken by the subcommittee under H. R. 441 of the Seventy-third Congress and other documentary data available on the subject, it was not deemed necessary by the Committee on Interstate and Foreign Commerce to conduct hearings on this bill.

While it is stated in the report to the Senate accompanying the Senate bill that it is a substantial but somewhat elaborated reenactment of the original section 9 (c), one will see from the mere reading thereof that it differed from section 9 (c) in many particulars. The Senate bill was permanent law, while 9 (c) was part of the National Industrial Recovery Act expiring in June 1935. Section 9 (c) was limited to shipments of petroleum and the products thereof, produced or withdrawn from storage in excess of the amount permitted to be produced or withdrawn from storage by any State law or valid regulation or order prescribed thereunder, etc., while the Senate bill covered such excess production by defining such production as "contraband oil" in the following language:

"Contraband oil (hot oil) shall be construed to mean crude petroleum and the liquid products, derivatives, and blends of crude petroleum, any part of which are produced, refined, processed, transported, withdrawn from storage, or otherwise handled in violation of any State law or valid orders, rules, or regulations prescribed thereunder, and the liquid products of such crude petroleum or petroleum products, derivatives or blends."

Section 9 (c) as part of the National Industrial Recovery Act was supported by a declaration of policy which differed very materially from the declaration adopted as part of this bill. The two differed radically in basic theory; 9 (c) delegated to the President the right to determine how much oil would move in interstate commerce, and the Senate bill, in effect, delegated that right to the oil States.

The definition of "contraband oil" as found in the bill after it passed the Senate was so broad as to cause some members of the committee to feel that a limitation imposed by State law, or valid orders, rules, or regulations, applied not only to production, but also refining and processing, and went entirely too far. The bill has been amended therefore, so as to limit this provision to petroleum or petroleum products, and any part of the constituent petroleum or products, which was produced or withdrawn from storage in excess of amounts permitted to be produced or withdrawn from storage under the laws of such State.

Instead of being permanent law, the committee has amended the bill so as to be temporary and to expire June 1, 1936. Two other important amendments to the Senate bill have been adopted, one, that under named circumstances the law shall be inoperative vesting in the President of the United States the authority to declare when the named circumstances exist; that is, to find when the supply of petroleum and the products thereof, moving in interstate commerce, is so limited as to cause in whole or in part a lack of parity between supply, including imports and withdrawals from storage. and demand, including exports and additions to storage, resulting in an undue burden on, or restriction of interstate commerce in petroleum and the products thereof. While there is a difference of opinion as to the legality of this language, the majority of the committee feel that it is within the four corners of the decision in the Panama and Amazon cases. For the information of the Members of the House, the opinion of Chief Justice Hughes and the dissenting opinion of Justice Cardozo in the Panama and Amazon cases can be found printed in the Congressional Record of January 7, 1935.

Section 9 (c) did not declare anything to be illegal until the President should so declare. In making such declaration, the Congress, in the opinion of the Supreme Court, did not require the President to adhere to any legislative policy, or to follow any standard laid down by it, or in fact to be guided by any rule. No particular circumstances, or conditions were set forth as a perquisite to the President's declaration. The Supreme Court construed this action by Congress to be an invalid delegation of authority.

In S. 1190, as amended, Congress declares in no uncertain terms that such shipments, or transportation, in interstate commerce as defined therein, is prohibited, and violations of such Federal law is punishable in the manner prescribed. Immediately upon the passage of this act, therefore, shipments in interstate commerce of petroleum and petroleum products, as defined, become a violation of the law, and there is no delegation of authority to the President to determine anything before such law would become operative. There is a proviso, however, which is inserted for one controlling reason. As the bill passed the Senate, provisions of State law as to quantity of petroleum and its products which might legally be shipped in interstate commerce, furnished the sole guide for Federal action. In extending support to the oil-producing States and accepting the decision of State law as to the quantity of production, this right possessed by the State must not be abused to the detriment of the consuming public. Some members of the committee felt that without the Senate bill being changed the agency of the Federal Government established as support to the States would be limited in the application of the law to the quantity of this resource, which could leave the producing sections of the country and cross State lines, exclusively be State law, and that that privilege might be abused. Other members of the committee did not feel that there was any occasion for alarm to this extent, because production in the producing States could not by law be curtailed to a point which the court would permit, if it violated the principles established in adjudicated cases, that production of crude oil could not be limited by State law in exercise of the policy power of the States, below a point that would be construed as a reasonable exercise of such power. In other words, limitation of production of petroleum under State law has been approved by the courts, and such limitations result from statutory law, having as its basis the prevention of waste and the conservation of this natural and limited resource.

The committee inserted the proviso found in the bill, which does not arbitrarily delegate to the President the power to declare the law to be inoperative in his sole discretion, but only when he finds that the circumstances exist which are set forth in the statute. Congress says to the President in effect in the language of the amendment—

"You are permitted to declare the existence of the facts by which this law shall be inoperative whenever you find that the supply of petroleum and the products thereof, moving in interstate commerce, is so limited as to cause in whole or in part a lack of parity between supply, including imports, and demand, including exports, resulting in an undue burden on, or restriction of, interstate commerce in petroleum and the products thereof."

Under this language the President, we assume, will require a factual basis for his finding, that factual finding being addressed to what limitation there is upon the supply moving in interstate commerce, and whether there is a lack of parity between such supply and demand. This is a definite requirement, a statement of circumstances and the imposition of conditions, all of which must be determined before the President can act. This power in the President presupposes a definite finding and a statement of the facts for the President's action before any such action is taken.

We specifically point out that this bill provides for "Federal control only as supporting the enforcement of the valid State law." It leaves to the oil-producing States the entire authority to determine how much or how little oil shall be produced in their jurisdictions. The bill in effect says to the oil States:

"The United States prohibits entry into interstate commerce of oil produced in violation of your law, provided the amount is not so limited as to be against the greater interest of the Nation. In that case the prohibition will be suspended."

Another amendment of importance is one requiring that "contraband, or hot oil" seized under violation of this bill be forfeited to the United States. The amendment, we think, is fair and constitutional. Every case might not justify the forfeiture of petroleum or petroleum products seized in apprehending the violator of the law under the bill, and for those cases carrying mitigating circumstances due protection has been provided. In the case of the hard-boiled violator who ships, for instance, by boat, large quantities of easily designated "hot" oil, we can see no reason when the agency of the Federal Government is required to apprehend such a violator and that violation, of course, against Federal law, that the property seized thereunder should not be forfeited to the Federal Government. It would be folly in dealing with such a defendant to impose a fine, the amount thereof being ridiculous as compared with the value of the cargo, to then turn around and deliver back to him the same goods which he had previously possessed in violation of the law and for which he had been convicted. We can conceive of cases where an innocent shipper might be technically guilty for the violation of such law, but it would be harsh and unreasonable to not deliver back to him in the State of production, or under such other arrangements as the court might impose, property which would be useful and of value.

The Senate bill, as amended by the Committee on Interstate and Foreign Commerce, was returned to the subcommittee for the preparation of the bill, as reported. It is tempting for that committee to give in this report something more in detail regarding the petroleum industry, the third largest in our country today, because we feel that it is a problem of paramount importance to the country and one that Members of Congress, regardless of whether they are from oil-producing States or the consuming section of the country, are interested. In lieu of such a statement at this time, and in view of the supplemental report which the subcommittee will file at a later date, we commend to the attention of the Members of Congress the hearings conducted by the subcommittee under H. R. 441 of the Seventy-third Congress. This was an investigation authorized by the Congress. We believe that upon reading these hearings Members of Congress will not only be benefited, but will see the entire justification for the study directed to be made of this very important industry so vital to the present and future existence of the Nation.

It is only fair to state that this bill does not wholly represent the views of the members, both of the committee and the subcommittee, as to the proper legislative remedy for the ills of the petroleum industry. This bill is essentially "stopgap" legislation to meet the objections pointed out by the Supreme Court in the "hot oil" cases to the constitutional validity of section 9 (c) of the National Industrial Recovery Act. If it is enacted, it will again check the movement of "hot oil" until the entire question can be more thoroughly considered.

[PUBLIC RESOLUTION—NO. 64—74TH CONGRESS]

[H. J. Res. 407]

JOINT RESOLUTION Consenting to an interstate oil compact to conserve oil and gas

*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That the consent of Congress is hereby given to an interstate compact to conserve oil and gas, executed in the city of Dallas, Texas, the 16th day of February, 1935, by the representatives of the States of Oklahoma, Texas, California, and New Mexico, and there recommended for ratification by representatives of the States of Arkansas, Colorado, Illinois, Kansas, and Michigan, and since ratified by the States of New Mexico, Kansas, Oklahoma, Illinois, Colorado, and Texas, which compact has been deposited in the Department of State of the United States, and reads as follows:

### "ARTICLE I

"This agreement may become effective within any compacting State at any time as prescribed by that State, and shall become effective within those States ratifying it whenever any three of the States of Texas, Oklahoma, California, Kansas, and New Mexico have ratified and Congress has given its consent. Any oil-producing State may become a party hereto as hereinafter provided.

### "ARTICLE II

"The purpose of this compact is to conserve oil and gas by the prevention of physical waste thereof from any cause.

### "ARTICLE III

"Each State bound hereby agrees that within a reasonable time it will enact laws, or if laws have been enacted, then it agrees to continue the same in force, to accomplish within reasonable limits the prevention of:

"(a) The operation of any oil well with an inefficient gas-oil ratio.

"(b) The drowning with water of any stratum capable of producing oil or gas, or both oil and gas in paying quantities.

"(c) The avoidable escape into the open air or the wasteful burning of gas from a natural-gas well.

"(d) The creation of unnecessary fire hazards.

"(e) The drilling, equipping, locating, spacing, or operating of a well or wells so as to bring about physical waste of oil or gas or loss in the ultimate recovery thereof.

"(f) The inefficient, excessive or improper use of the reservoir energy in producing any well.

"The enumeration of the foregoing subjects shall not limit the scope of the authority of any State.

### "ARTICLE IV

"Each State bound hereby agrees that it will, within a reasonable time, enact statutes, or if such statutes have been enacted then that it will continue the same in force, providing in effect that oil produced in violation of its valid oil and/or gas conservation statutes or any valid rule, order, or regulation promulgated thereunder, shall be denied access to commerce; and providing for stringent penalties for the waste of either oil or gas.

### "ARTICLE V

"It is not the purpose of this compact to authorize the States joining herein to limit the production of oil or gas for the purpose of stabilizing or fixing the price thereof, or create or perpetuate monopoly, or to promote regimentation, but is limited to the purpose of conserving oil and gas and preventing the avoidable waste thereof within reasonable limitations.

### "ARTICLE VI

"Each State joining herein shall appoint one representative to a Commission hereby constituted and designated as 'The Interstate Oil Compact Commission,' the duty of which said Commission shall be to make inquiry and ascertain from time to time such methods, practices, circumstances, and conditions as may be disclosed for bringing about conservation and the prevention of physical waste of oil and gas, and at such intervals as said Commission deems beneficial it shall report its findings and recommendations to the several States for adoption or rejection.

"The Commission shall have power to recommend the coordination of the exercise of the police powers of the several States within their several jurisdictions to promote the maximum ultimate recovery from the petroleum reserves of said States, and to recommend measures for the maximum ultimate recovery of oil and gas. Said Commission shall organize and adopt suitable rules and regulations for the conduct of its business.

"No action shall be taken by the Commission except: (1) by the affirmative votes of the majority of the whole number of the compacting States, represented at any meeting, and (2) by a concurring vote of a majority in interest of the compacting States at said meeting, such interest to be determined as follows: Such vote of each State shall be in the decimal proportion fixed by the ratio of its daily average production during the preceding calendar half-year to the daily average production of the compacting States during said period.

### "ARTICLE VII

"No State by joining herein shall become financially obligated to any other State, nor shall the breach of the terms hereof by any State subject such State to financial responsibility to the other States joining herein.

### "ARTICLE VIII

"This compact shall expire September 1, 1937. But any State joining herein may, upon sixty days' notice, withdraw herefrom.

"The representatives of the signatory States have signed this agreement in a single original which shall be deposited in the archives of the Department of State of the United States, and a duly certified copy shall be forwarded to the Governor of each of the signatory States.

"This compact shall become effective when ratified and approved as provided in Article I. Any oil-producing State may become a party hereto by affixing its signature to a counterpart to be similarly deposited, certified, and ratified.

"Done in the City of Dallas, Texas, this 16th day of February 1935."

"SEC. 2. The right to alter, amend, or repeal the provisions of section 1 is hereby expressly reserved.

Approved, August 27, 1935.

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[H. R. 9053, 74th Cong., 1st sess.]

[Omit the part enclosed in black brackets and insert the part printed in italic]

A BILL To regulate interstate and foreign commerce in petroleum and its products, to establish the Petroleum Administrative Board, and for other purposes

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,*

### CONSENT OF CONGRESS TO STATE OIL AND GAS COMPACT OF FEBRUARY 16, 1935

SECTION 1. The consent of Congress is hereby given to an interstate compact to conserve oil and gas, executed in the city of Dallas, Texas, the 16th day of February, 1935, by the representatives of the States of Oklahoma, Texas, California, and New Mexico, and there recommended for ratification by representatives of the States of Arkansas, Colorado, Illinois, Kansas, and Michigan, and since ratified by the States of New Mexico, Kansas, Oklahoma, Illinois, Colorado, and Texas, which compact has been deposited in the Department of State of the United States, and reads as follows:

### "ARTICLE I

"This agreement may become effective within any compacting State at any time as prescribed by that State, and shall become effective within those States ratifying it whenever any three of the States of Texas, Oklahoma, California, Kansas, and New Mexico have ratified and Congress has given its consent. Any oil-producing State may become a party hereto as hereinafter provided.

### "ARTICLE II

"The purpose of this compact is to conserve oil and gas by the prevention of physical waste thereof from any cause.

### "ARTICLE III

"Each State bound hereby agrees that within a reasonable time it will enact laws, or if laws have been enacted, then it agrees to continue the same in force, to accomplish within reasonable limits the prevention of:

"(a) The operation of any oil well with an inefficient gas-oil ratio.

"(b) The drowning with water of any stratum capable of producing oil or gas, or both oil and gas in paying quantities.

"(c) The avoidable escape into the open air or the wasteful burning of gas from a natural-gas well.

"(d) The creation of unnecessary fire hazards.

"(e) The drilling, equipping, locating, spacing, or operating of a well or wells so as to bring about physical waste of oil or gas or loss in the ultimate recovery thereof.

"(f) The inefficient, excessive or improper use of the reservoir energy in producing any well.

"The enumeration of the foregoing subjects shall not limit the scope of the authority of any State.

### "ARTICLE IV

"Each State bound hereby agrees that it will, within a reasonable time, enact statutes, or if such statutes have been enacted then that it will continue the same in force, providing in effect that oil produced in violation of its valid oil and/or gas conservation statutes or any valid rule, order, or regulation promulgated thereunder, shall be denied access to commerce; and providing for stringent penalties for the waste of either oil or gas.

### "ARTICLE V

"It is not the purpose of this compact to authorize the States joining herein to limit the production of oil or gas for the purpose of stabilizing or fixing the price thereof, or create or perpetuate monopoly, or to promote regimentation, but is limited to the purpose of conserving oil and gas and preventing the avoidable waste thereof within reasonable limitations.

### "ARTICLE VI

"Each State joining herein shall appoint one representative to a Commission hereby constituted and designated as 'The Interstate Oil Compact Commission,' the duty of which said Commission shall be to make inquiry and ascertain from time to time such methods, practices, circumstances, and conditions as may be disclosed for bringing about conservation and the prevention of physical waste of oil and gas, and at such intervals as said Commission deems beneficial it shall report its findings and recommendations to the several States for adoption or rejection.

"The Commission shall have power to recommend the coordination of the exercise of the police powers of the several States within their several jurisdictions to promote the maximum ultimate recovery from the petroleum reserves of said States, and to recommend measures for the maximum ultimate recovery of oil and gas. Said Commission shall organize and adopt suitable rules and regulations for the conduct of its business.

"No action shall be taken by the Commission except: (1) by the affirmative votes of the majority of the whole number of the compacting States, represented at any meeting, and (2) by a concurring vote of a majority in interest of the compacting States at said meeting, such interest to be determined as follows: Such vote of each State shall be in the decimal proportion fixed by the ratio of its daily average production during the preceding calendar half-year to the daily average production of the compacting States during said period.

### "ARTICLE VII

"No State by joining herein shall become financially obligated to any other State, nor shall the breach of the terms hereof by any State subject such State to financial responsibility to the other States joining herein.

### "ARTICLE VIII

"This compact shall expire September 1, 1937. But any State joining herein may, upon sixty days' notice, withdraw herefrom.

"The representatives of the signatory States have signed this agreement in a single original which shall be deposited in the archives of the Department of State of the United States, and a duly certified copy shall be forwarded to the Governor of each of the signatory States.

"This compact shall become effective when ratified and approved as provided in Article I. Any oil-producing State may become a party hereto by affixing its signature to a counterpart to be similarly deposited, certified and ratified.

"Done in the City of Dallas, Texas, this 16th day of February 1935."

(b) The right to alter, amend, or repeal the provisions of subsection (a) is hereby expressly reserved.

### PETROLEUM ADMINISTRATIVE BOARD

SEC. 2. There is hereby established a Petroleum Administrative Board (referred to in this Act as the "Board") to be composed of five members to be appointed by the President by and with the advice and consent of the Senate. No member of the Board shall engage in any other business, vocation, or employment than that of serving as such member, nor shall any member of the Board participate directly or indirectly in any operation or transaction of a character subject to regulation by the Board under any provision of law. Each member of the Board shall receive a salary at the rate of **[**$12 000**]** *$10,000* a year and shall hold office for a term of five years, except that (1) any member of the Board appointed to fill a vacancy occurring prior to the expiration of the term for which his predecessor was appointed shall be appointed for the remainder of such term, and (2) the terms of office of the members of the Board first taking office after the date of the enactment of this Act shall expire, as designated by the President at the time of nomination, one at the end of one year, one at the end of two years, one at the end of three years, one at the end of four years, and one at the end of five years, after the date of the enactment of this Act.

### POWERS, DUTIES, AND FUNCTIONS OF THE BOARD

SEC. 3. (a) The Board is authorized and empowered, when in its judgment it is necessary for the purpose of administering the provisions of this Act, to make investigations and collect data from the petroleum industry, and to this end it may require periodical and special reports from persons in the petroleum industry and conduct examinations and inspections for the purpose of verifying such reports and ascertaining the facts. The Board may cooperate with the executives, officials, and agencies of the several States and with any agency created under the interstate compact to which the consent of Congress is given by this Act, in the study and investigation of matters relating to the petroleum industry, and may hold joint hearings upon such matters with any duly authorized State agency. The Board is authorized and directed to study and investigate, and in doing so to cooperate with, and when deemed advisable to hold joint hearings with executives, officials, and agencies of the several States and with any agency created under the interstate compact to which the consent of Congress is given by this Act, the status of petroleum reserves and sources of supply, the discovery and orderly development of sources of supply, improved methods of production, the possibility and expense of repressuring existing fields, and related matters pertaining to the petroleum industry. The several departments and independent establishments of the United Staes Government shall, at the request of the Board, provide it with all records and information which they may have available pertaining to the petroleum industry.

(b) The Board shall determine periodically (1) the reasonable market demand for petroleum to be produced in the United States, and (2) that part of such demand which constitutes the reasonable market demand of petroleum to be produced in each producing State, specifically determining the quantity required from current production to supply such demand for petroleum from each producing State. The demand for petroleum as so periodically determined by the Board shall be within such limit as is consistent with the prevention of physical waste, and determined after fair and impartial consideration of pertinent information submitted by any commission, officer, or other agency established or designated under State law for the purpose of conserving oil and gas and preventing the physical waste thereof in any State, the systematic analysis of appropriate statistical data, and consultation with such sources of information within the petroleum industry as it may be necessary, and consultation with any agency created under the interstate compact to which the consent of Congress is given by this Act. The Board shall inform any duly constituted State authority charged under State law with the duty of regulating or restricting the production of petroleum, or the Governor of any oil-producing State having no such State authority, of its determinations, and shall also give public notice of such determinations.

(c) The President may, at any time, by Executive order, transfer to the Board the whole or any part of any office, bureau, or division in the executive branch of the Government engaged in statistical, economical, legal, scientific. or administrative work affecting or related to the production, refining, transportation, or marketing of petroleum or petroleum products, and in the case of any such transfer (1) all powers, duties. and functions imposed upon or vested in the department or agency from which such transfer is made or upon the secretary or chief executive officer thereof, in relation to the office, bureau, or division or part thereof so transferred, shall be imposed upon and vested in the Board, (2) all employees, property, and records of such office, bureau, or division, or part thereof, shall be transferred to the Board, and (3) unexpended balances of appropriations used by or available to such office, bureau, or division, or part thereof, shall be available for expenditure by the Board.

### AMENDMENTS PLACING ADMINISTRATION OF ACT OF FEBRUARY 22, 1935, IN PETROLEUM ADMINISTRATIVE BOARD

SEC. 4. (a) Section 2 of the Act of February 22. 1935, entitled "An Act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes", is amended by adding at the end thereof a new paragraph as follows:

"(5) The term 'Board' means the Petroleum Administrative Board created by the Petroleum Act of 1935."

(b) Section 5 of such Act of February 22, 1935, is amended to read as follows:

"SEC. 5. (a) The Board shall prescribe such regulations as it finds necessary or appropriate for the enforcement of the provisions of this Act, including but not limited to regulations requiring reports, maps, affidavits, and other documents relating to the production, storage, refining, processing transporting, or handling of petroleum and petroleum products, and providing for the keeping of books and records, and for the inspection of such books and records and of properties and facilities.

"(b) Whenever the Board finds it necessary or appropriate for the enforcement of the provisions of this Act it shall require certificates of clearance for petroleum and petroleum products moving or to be moved in interstate commerce from any particular area. A certificate of clearance shall be issued by the Board in any case where it determines that the petroleum or petroleum products in question do not constitute contraband oil. Denial of any such certificate shall be by order, and only after reasonable opportunity for hearing. Whenever a certificate of clearance is required for any area in any State, it shall be unlawful to ship or transport petroleum or petroleum products in interstate commerce from such area unless a certificate has been obtained therefor.

"(c) Any person whose application for a certificate of clearance is denied may obtain a review of the order denying such application in the United States District Court for the district wherein the Board is sitting by filing in such court within thirty days after the entry of such order a written petition praying that the order of the Board be modified or set aside, in whole or in part. A copy of such petition shall be forthwith served upon the Board, and thereupon the Board shall certify and file in the court a transcript of the record upon which the order complained of was entered. Upon the filing of such transcript, such court shall have jurisdiction to affirm, modify, or set aside such order, in whole or in part. No objection to the order of the Board shall be considered by the court unless such objection shall have been urged before the Board. The findings of the Board as to the facts, if supported by evidence, shall be conclusive. The judgment and decree of the court shall be final, subject to review as provided in sections 128 and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 225 and 347)."

(c) Subsection (b) of section 7 of such Act of February 22, 1935, is amended by striking out the words "a board created under authority of section 5" and inserting in lieu thereof the words "the Board."

(d) Section 8 of such Act of February 22, 1935, is amended by striking out the words "a board created under authority of section 5" and inserting in lieu thereof the words "the Board."

(e) Section 9 of such Act of February 22, 1935, is amended to read as follows:

"SEC. 9. The Board, and any agency, officer, or employee designated under authority of section 11, may hold and conduct such hearings, investigations, and proceedings as may be necessary for the purposes of this Act, and for such purposes those provisions of section 21 of the Securities Exchange Act of 1934 relating to the administering of oaths and affirmations, and to the attendance and testimony of witnesses and the production of evidence (including penalties). shall apply."

(f) Subsections (a) and (b) of section 10 of such Act of February 22, 1935, are amended to read as follows:

"SEC. 10. (a) Upon application of the Board, by the Attorney General, the United States District Courts shall have jurisdiction to issue mandatory injunctions commanding any person to comply with the provisions of this Act or any regulation issued thereunder.

"(b) Whenever it shall appear to the Board that any person is engaged or about to engage in any acts or practices that constitute or will constitute a violation of any provision of this Act or of any regulation thereunder, it may in its discretion, by the Attorney General, bring an action in the proper United States District Court to enjoin such acts or practices, and upon a proper showing a permanent or temporary injunction or restraining order shall be granted without bond."

(g) Section 11 of such Act of February 2, 1935, is amended by striking out the word "President" wherever it appears therein and inserting in lieu thereof the word "Board."

(h) All orders, certificates, findings, determinations, requirements, or regulations which have been issued, made, or granted prior to the enactment of this Act, under authority of any provision of such Act of February 22, 1935, which after the enactment of this Act is to be administered by the Board, and which are in effect at the time of the enactment of this Act, shall continue in effect until modified, terminated, superseded, or repealed by the Board or by operation of law. Any hearing, investigation, or proceeding pending under such Act of February 22, 1935, at the time of the enactment of this Act, shall be continued by the Board in the same manner as though originally commenced by or before the Board. No suit, action, or other proceeding lawfully commenced by or against any agency or officer in relation to the exercise or discharge of powers or duties under authority of any provision of such Act of February 22, 1935, which after the enactment of this Act is to be administered by the Board, shall abate by reason of the transfer of such powers or duties, but the court may allow such suit, action, or proceeding to be maintained by or against the Board. There are hereby transferred to the jurisdiction of the Board all records of any agency heretofore designated by the President for the execution of any powers or duties under such Act of February 22, 1935, insofar as such records pertain to matters to which such Act relates.

## IMPORTS

SEC. 5. The importation of petroleum and its products, including natural asphalt is hereby limited so that whenever the Board has reason to believe that petroleum and its products, including natural asphalt, are being imported or are likely to be imported into the United States under such conditions and in such quantities as to render ineffective or materially interfere with any program or operation undertaken under this Act, under the interstate compact to which the consent of Congress is given by this Act, or under the Act of February 22, 1935, hereinbefore referred to, the Board shall cause an immediate investigation to be made to determine such facts. Such investigation shall be made after such notice and hearing, and subject to such regulations as the Board shall specify. If, after such investigation, the Board finds the existence of such facts, it shall certify all records pertaining thereto to the President and if after such report, findings, and recommendations by the Board, the President finds the existence of such facts he shall by order direct that the entry into the United States of such petroleum and its products, including asphalt, shall for such time as may be specified by him, be permitted subject to (1) such terms and conditions, and (2) such limitations on the total quantities thereof, as may be necessary to prevent the occurrence or continuance of the conditions above referred to. Any decision of the President as to facts under this section shall be final. The decision of the President shall be certified to the Board and upon information of any such order of the President, the Secretary of the Treasury shall permit entry of any petroleum, or its products, including natural asphalt, specified therein only in conformity with such order. After investigation, report, and finding in the manner provided in the case of an original order, any order or provision thereof shall be suspended or revoked by the President whenever he finds the circumstances requiring the order or provision thereof no longer exist, or shall be modified by the President whenever he finds that changed circumstances require such modification to carry out the provisions of this section.

### VOLUNTARY INDUSTRIAL AGREEMENTS

SEC. 6. The Board is authorized to provide for the holding of meetings and conferences and to assist otherwise in the formulation of voluntary agreements between members of the petroleum industry whereby (1) the production of crude petroleum in such manner, in such amount, or under such conditions as to constitute waste may be avoided; or (2) the orderly, systematic, and scientific development of oil fields or pools may be accomplished; or (3) petroleum refineries may be operated in such manner that nonintegrated or semi-integrated refineries may compete on a fair basis with the refining units of integrated organizations in the oil industry, the processing of crude petroleum may conform with and support the crude petroleum production orders issued by State conservation authorities or conform with agreements which may be entered into under clause (1) of this section, and that equitable access to sources of crude petroleum supply may be achieved; or (4) nonintegrated or semi-integrated producers, refiners, and marketers may be assured fair access to markets. If the President, after investigation and report by the Board, finds that any such agreement will accomplish one or more of the purposes above specified *and that the same is in the public interest*, he shall by order approve such agreement and upon such approval such agreement shall be valid and effective, and such agreement and action taken thereunder while such agreement is in effect shall be exempt from the provisions of the antitrust laws of the United States. The President, after investigation and report by the Board, shall by order withdraw his approval of any such agreement, and such agreement shall thereupon cease to be in effect, whenever he finds that such agreement or operations thereunder fail to accomplish one or more of the purposes above stated *or is not in the public interest*. In any such investigation reasonable opportunity for hearing shall be afforded interested parties. No such agreement shall be approved unless it provides for the payment of adequate minimum wages to employees, and for the maintenance of fair maximum hours of labor for employees.

### ADMINISTRATIVE PROVISIONS

SEC. 7. (a) Wherever reference is made in this Act to the Board such reference shall be held to include, in addition to the Board, any agency, officer, or employee who may be designated by the Board for the execution of any of the powers and functions vested in the Board under this Act.

(b) The Board, and any agency, officer, or employee designated under authority of subsection (a), may hold and conduct such hearings, investigations, and proceedings as may be necessary for the purposes of this Act, and for such purposes those provisions of section 21 of the Securities Exchange Act of 1934 relating to the administering of oaths and affirmations, and to the attendance and testimony of witnesses and the production of evidence (including penalties), shall apply.

(c) The Board shall have power to perform any and all acts, and to prescribe, issue, make, amend, and rescind such rules and regulations as it may find necessary or appropriate to carry out the provisions of this Act.

(d) The Board is authorized to appoint and fix the compensation of such officers, attorneys, examiners, and experts as may be necessary for carrying out its functions under this Act or under any other provision of law, without regard to the provisions of other laws applicable to the employment and compensation of officers and employees of the United States, and the Board may, subject to the civil-service laws, appoint such other officers and employees as are necessary in the execution of such functions and fix their salaries in accordance with the Classification Act of 1923, as amended.

### ANNUAL REPORT

SEC. 8. The Board shall make an annual report to Congress regarding the operations of the Board; and there shall be included in such report such information and data collected by the Board as may be of value in the determination of matters relating to the petroleum industry, and such recommendations for additional legislation as the Board deems advisable relating to such matters.

### SEPARABILITY OF PROVISIONS

SEC. 9. If any provision of this Act, or the application of such provision to any person or circumstance, shall be held invalid, the remainder of the Act, and the application of such provision to persons or circumstances other than those as to which it is held invalid, shall not be affected thereby.

### SHORT TITLE

SEC. 10. This Act may be cited as the "Petroleum Act of 1935."

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[H. Rept. No. 1801, 74th Cong., 1st sess.]

The Committee on Interstate and Foreign Commerce, to whom was referred the bill (H. R. 9053) to regulate interstate and foreign commerce in petroleum and its products, to establish the Petroleum Administrative Board, and for other purposes, having considered and amended the same, report thereon with a recommendation that it pass.

Amend the bill as follows:

Page 6, line 16, change "$12,000" to "$10,000."

Page 17, line 7, after the word "specified," insert "and that the same is in the public interest."

Page 17, line 17, after the word "stated," insert "or is not in the public interest."

H. R. 9053 is the recommendation of the subcommittee of the Interstate and Foreign Commerce Committee of the House, which subcommittee in the last session of Congress investigated the petroleum industry.

House Joint Resolution No. 441 of the Seventy-third Congress, directing the investigation of the petroleum industry aforesaid provided for report to the Seventy-third Congress. Because of the preliminary character of the report submitted as hereinafter discussed, there is no authority for the subcommittee, in response to the said resolution, to file what might be considered a final report. H. R. 9053 might be accepted therefore as the final report of the subcommittee with reservations on the part of one member of the subcommittee as hereinafter presented, which reservations are also the views of three other members of the full committee.

In the preliminary report filed January 2, 1935, pursuant to House Resolution No. 441 (73d Cong.), the subcommittee had the following to say:

"We have not deemed it advisable at this time to set forth in this report or to prepare for introduction when Congress convenes on January 3 a bill or bills embodying our conception of what permanent and/or temporary legislation should be enacted by the Seventy-fourth Congress dealing with the petroleum industry. There are numerous reasons for our taking this position. In the first place, the National Industrial Recovery Act, though temporary, has through its provisions, and rules and regulations passed thereunder, helped the petroleum industry to some extent. At this time, for instance, the operation of the Federal Tender Board is given a great deal of credit for production being fairly in line with the demand established by the Federal Government. We anticipate that some of the pending temporary legislation will become permanent. Because of the constitutional difficulties which have arisen in the last 18 months in the administration of the Petroleum Code and other provisions of the National Industrial Recovery Act pertaining to petroleum, we feel that the decision by the Supreme Court of the United States in the Amazon and Panama cases should be very helpful to Congress in drafting legislation. The National Resources Board appointed by President Roosevelt early last summer to make a study of national, including natural, resources has just submitted an exhaustive report, volume 1 thereof being the only one available to the subcommittee at this time. Volume 5 evidently will deal with our natural resources and it is important that the information and recommendations therein be known to Congress before definite legislation is considered.

"Another reason for not submitting legislation with this report is the pending effort of the Governors of oil-producing States to effect an interstate compact. We have made reference to the first meeting of the Governors' conference on December 3 last. A second meeting will be held simultaneously with the convening of the Seventy-fourth Congress. We strongly urge upon the oil-producing States the adoption of State compacts to deal with the problems of the production of petroleum with which individual States are powerless to cope. The subcommittee clearly recognizes the principle of State compacts for the purpose of effecting a common end of State interests. Other plans for dealing with the problems of petroleum production outside of State lines are full of constitutional questions. State compacts, flexible in operation and over which the President of the United States or a Federal agency in the interest of the consuming masses of the Nation, may hold some veto power, is a solution of those problems of petroleum production which cannot be solved by modification of the "law of capture" and other legislation operating within State boundaries. We are confident that the Governors of the oil-producing States and the majority of the industry within those States are cognizant of the common-sense theory that waste of petroleum resources must be prevented. Huge waste, such as the subcommittee has witnessed in the Panhandle of west Texas, should not be permitted to continue. Waste of many kinds in other fields, both past and present, shock anyone possessing familiarity therewith.

"At the meeting of the Governors and Governors-elect and representatives of Governors, held on December 3, various important resolutions looking to the formation of an interstate compact were offered. It is the understanding of the subcommittee that these resolutions will be before the second meeting on January 3, 1935. This discussion and consideration by the Governors of our oil-producing States coming at this time, when the legislatures of all of these States are either in session or about to convene, presents ample opportunity for the oil-producing States through actual agreement and approval to present to the Seventy-fourth Congress before its adjournment a definite, specific compact for its consideration. It will not take many weeks after January 3 for the Congress to decide whether the effort of the Governors of the oil-producing States promises worth-while results. We believe they should be given the opportunity to take the initiative in drafting definite proposals without the Congress setting forth in a permissive way something in advance for the States to adopt. Something real and substantial may grow out of the pending effort. If it does not the Seventy-fourth Congress will have ample time to pass such legislation as may be necessary.

"The determination of the necessity, extent, and character of possible legislation depends in part upon the question of whether an excessive supply of petroleum exists. There may be a difference of opinion as to whether "excessive supply" of petroleum and its products means supply available to meet current demand, or reserves available to meet future demand.

"We recommend, therefore, that any legislation establishing permanently the interest of the Federal Government in the petroleum industry should provide for an agency, commission, or board, as it might be designated, to absorb some of the activities in various departments of the Federal Government as now constituted. The Bureau of Mines might very easily be revamped for the purpose.

"The subcommittee feels that such an agency should have sufficient personnel and authority to study continuously the status of the petroleum reserves; encourage discoveries of new pools; assist in improving present-day methods of production; study the possibility and expense of repressuring in various existing fields; systematically determine the total demand for petroleum and its products, both domestic and foreign; have jurisdiction over the management of oil-producing public and Indian lands; be given jurisdiction to establish pipe-line rates, unless the Interstate Commerce Commission is given greater appropriation to handle more expeditiously this subject now before it; and to study and make report as to the advisability of divorcing pipe lines; recommend at regular intervals to the President of the United States—the President being given authority by Congress to approve—limitations upon the importation of petroleum and its products, including natural asphalt, so as to prevent importation thereof from interfering with current domestic production by supplying an undue proportion of the domestic consumption and export demand therefor; to represent the Federal Government, if need be, in any cooperative interstate compact agreed upon and approved by the Congress; and, in general, to possess all other necessary authority so as to present that dignity, from a national standpoint, to which the subcommittee believes the petroleum industry is entitled.

"Coal, timber, and other natural resources might properly also be included under the jurisdiction of this agency.

"We are convinced that not sufficient attention is being paid to the interest of consumers of petroleum products. Settlements of so-called 'price wars,' which result in some cases in an increase of 100 percent in the cost of gasoline, strain the credulity of the observer on the theory that they just happened without prearrangement in view of the fact that the Sherman Antitrust Act is still the law of the land, except insofar as temporarily it may be suspended by the operation of the National Industrial Recovery Act, we think that the fixing of gasoline prices is a matter worthy of close and constant scrutiny by the Department of Justice.

"It is the purpose of the members of this subcommittee, all of whom have been reelected to the Seventy-fourth Congress, to ask the permission of the Seventy-fourth Congress to file a supplemental report when the decision of the Supreme Court in the *Panama* and *Amazon cases* shall have been rendered, the result of the Governors' conference, now in session with respect to an interstate compact, shall have been concluded, and the full report of the National Resources Board shall have been published."

Following the decision of the Supreme Court in the *Panama* and *Amazon cases* (the opinion printed in Congressional Record of January 7, 1935), S. 1190, S. 1190, seeking to enact new legislation which would be constitutional, accomplishing the same purpose as section 9–C of the National Industrial Recovery Act, which section was declared unconstitutional in the aforesaid case, was introduced. S. 1190 was reported out by the Interstate and Foreign Commerce Committee of the House and in reporting that bill and advocating its passage the report contained the following statement:

"It is only fair to state that this bill does not wholly represent the views of the members, both of the committee and the subcommittee, as to the proper legislative remedy for the ills of the petroleum industry. This bill is essentially 'stopgap' legislation to meet the objections pointed out by the Supreme Court in the 'hot oil' cases to the constitutional validity of section 9 (c) of the National Industrial Recovery Act. If it is enacted, it will again check the movement of 'hot oil' until the entire question can be more thoroughly considered."

In the early part of the session a bill dealing with control and regulation of the petroleum industry was introduced by Senator Thomas of Oklahoma and subsequently a new bill in the form of amendments to the original was also introduced by Senator Thomas. In anticipation of this bill, which has been the subject of hearings before the Senate Committee on Mines and Mining and reported out, and now on the Senate calendar, being passed by the Senate in some form and later being referred to the Committee on Interstate and Foreign Commerce of the House for consideration, no legislation was recommended by the subcommittee dealing with the subject other than the Connally bill referred to.

The subcommittee now feels, in view of the investigation conducted pursuant to House resolution aforesaid and the reasons stated in the report of January 2, 1935, for not recommending at that time concrete legislation, now no longer existing, it is to be expected—in fact, it is their duty—to give some final expression to their views on this very important subject. As the initial report of the subcommittee will disclose, they gave during the investigation considerable encouragement to the formation of the Interstate compact and are glad to state in this report that which is known to many Members of the House, that through the efforts of many progressive Governors of a number of the oil-producing States, and we feel to some extent as a result of the encouragement of the subcommittee, such a compact has been entered into.

Gov. E. W. Marland, of Oklahoma, acting in behalf of the representatives of those signatories to the compact, transmitted the compact to the President of the United States and the chairman of the aforesaid subcommittee, with the request that such legislation as may be appropriate to ratify the compact might be passed at this session. The compact is set forth in full in section 1 of H. R. 9053.

It will be noted the great States of Texas, Oklahoma, California, Kansas, New Mexico, Arkansas, Colorado, Illinois, and Michigan are parties to the compact and that the legislatures of the States of New Mexico, Oklahoma, Kansas, Colorado, Texas, and Illinois have to date ratified.

The delay in the present Congress in requesting ratification of the aforegoing compact might be attributed to an honest desire and effort on the part of the President and others, including many Members of Congress, to work out in some agreeable way a bill ratifying said compact and at the same time including advisable supplemental legislation. Many conferences, many letters and telegrams looking to this have occupied the interim between the receipt of the compact and the present time. It is fair to state that some Members of the House have intended to introduce oil legislation at this session but have deferred such action with the hope that a report of the subcommittee aforesaid might be submitted. Following the introduction of H. R. 9053, Representative Disney, of Oklahoma, who introduced the bill in the Seventy-third Congress which brought about the investigation aforesaid, introduced an identical bill.

H. R. 9053 differs in many respects from the original Thomas-Disney bills but it is, in the judgment of the committee, as far as Congress should go on this subject and includes all legislation necessary to meet the problem as it exists today and, we hope, for all time.

This bill in detail does the following:

It provides for ratification of the interstate compact, realizing that the compact itself is not the strongest document of the kind that could be drawn but that it is an initial effort on the part of the oil-producing States to meet, in a constitutional way, the prevention of waste of this great resource and in that way the conservation thereof. The compact bespeaks an effort on the part of a number of States to meet a great problem which is peculiarly a State one and yet the magnitude of which flows over into every State of the Union, thereby making it one of real national interest. The right of the States to handle and control the production end of this industry is one that the committee recognized and wants to encourage. The problem is not too big for the States if they sincerely want to solve it, at the same time it is not one which will tolerate abandonment or trifling by the State. The country as a whole has the right to demand that petroleum, a great God-given resource belonging as a whole to no State or individual, but a natural national resource, must be conserved and must not be wasted. Petroleum has admittedly become an integral, indispensable part of almost every activity of our country, both private and public. It presents a problem which the committee recognizes as belonging in a large measure to the States for solution, but in order for the States to succeed in such an effort they must have the cooperative help of the Federal Government.

If many other problems, involving production, peculiar to a known number of States, had been handled through the compact procedure as a real and genuine effort on the part of the interested States to solve such problem, and that, approved by Congress, much legislation heretofore passed by Congress dealing with production of many commodities would have been unnecessary. When Congress gives approval, however, to a compact of the type set forth in section 1 of this bill, giving to the principal oil-producing States control of production of petroleum, supplemental legislation is necessary and advisable to the extent included in this bill. Section 2 provides for a Petroleum Administrative Board, an independent agency of the Federal Government. The members of this Board are to be appointed by the President with the advice and consent of the Senate. The duties of the Board make it advisable in our judgment for a separate agency instead of some bureau chief, or agency appointed by a Cabinet member without the approval of the President or the Senate to administer its provisions. The petroleum industry is our third largest industry, railroads and agriculture being the only two exceeding it in investment. Since the World War this industry has been the subject of ever-recurring investigation and study on the part of the Federal Government. President Coolidge sensed the importance of the President and Congress knowing at all times, if possible, the status of our petroleum reserves, and of the necessity for rigid waste-prevention measures and, in general, the preservation as long as might be possible, of a resource of almost immeasurable value, admittedly indispensable at this time to enumerable activities and yet of a limited quantity. President Hoover and President Roosevelt have likewise expressed their keen interest in a similar way. The quantity of petroleum in the country today is pretty well known and no one will deny that while there is more than is necessary to meet current demand, it is shockingly low to meet future demand. New discoveries it is true will be made, but such new discoveries should be accompanied by a greater respect on the part of developers of such fields looking to ultimate recovery from such fields, or pools, than has been the experience of the past in the shocking conduct of operators in the larger fields of the country.

Section 3 covers the powers, duties, and functions of the Board. Such duties present no encroachment whatsoever by the Federal Government upon the prerogatives of the States. The Board is the agency of the entire country and not the agency of the producing States alone, which agency however is to cooperate in every helpful way with the interstate compact group in carrying out the purposes and objects set forth in the compact. The proposed Board is to know, as near as possible, at all times, the status of petroleum reserves and sources of supply. It is to study and investigate the discovery and orderly development of all sources of supply and improved methods of production, as well as the possibility and the expense of repressuring existing fields. All of these subjects, as well as many others of a technical, geological, and engineering character, are known to the lay mind, not to say anything of one who is familiar with the industry and its ramifications. The importance of such information being in the possession of the Federal Government is too important to need any elaboration in this report. The Board has the important function of determining the total demand for petroleum to be produced in the United States, including domestic consumption, additions to storage, and export requirements. This aggregate figure is then divided and each producing State informed by the Board of the division, after the Board has taken into consideration all pertinent information necessary in order to make a fair allocation or determination. Such pertinent information will necessarily include limitation upon production from any pool to the point that waste will be prevented. It will take into consideration also the potential of such pools, the investments therein, the refining, transportation, and marketing activities associated therewith. Bear in mind this finding by the Board is not imposed upon the States in any mandatory fashion whatsoever. It is totally advisory and can be accepted by the States as a limitation upon the production therein, in any way the State might determine. This finding by a Federal agency has been pretty generally conceded by witnesses in the hearings before the subcommittee as advisable. It is our belief that the producing States will give serious consideration to this finding, in determining through the State conservation boards the production allowables in the respective States.

Further justification for an independent board might be requested. This Congress passed in the early part of the session, S. 1190, which legislation provides for tender boards to be set up to administer the provisions of that law. These boards, without any limitation upon the number, depending entirely upon the necessity therefor, are paid salaries of $5,000 to each member. One board is now in existence in east Texas. The board created under H. R. 9053 takes over completely the administration of S. 1190 (the so-called Connally bill), and makes unnecessary the appointment of tender boards as therein provided. The administration of the Connally bill will be carried out by the board created in this act through the employees of the board just the same as other comparable functions of the Federal Government under other boards. This bill provides for limitation upon imports of petroleum and voluntary industrial agreements within the industry, all of which come under the duties of this board.

The program lodged within the four corners of this bill is too important to be vested, as to its administration, in the hands of a bureau head, or a subordinate agency of some Cabinet official. It should be dignified in the way this great industry deserves, with the appointment of a board by the President with the approval of the Senate, so that with all the duties it has upon it, it will reflect that dignity, and that position which other great industries of the country enjoy in the distinction they have so far as Federal interest in their problems is established. This provision of the bill establishing a separate board and imposing the very important duties thereon has had the most serious and careful attention of the committee and the large majority of the committee feel very strongly that it is most important that it be retained substantially in the form we have recommended.

Section 4 of the bill places the administration of the Connally Act, passed on February 22, 1935, under the new board and transfers all appropriations given to provide for the administration of the Connally Act, to the new board. This includes, as we expect, the $500,000 recently provided in the deficiency bill for the administration of the Connally Act.

Section 5 provides for regulation of imports and is quite similar in language to the import provisions of the recent amendments to the Agricultural Adjustment Act. It says that the President, upon factual finding by the Board, shall limit importation of petroleum whenever it is found that the importation of petroleum, including natural asphalt, into the United States is in such quantities as to render ineffective, or materially interfere with the program undertaken in this act. That means in brief this: This bill sanctions production control by the States to the extent that such control can be regulated under waste-prevention statutes as a legal exercise of the police power of the States, and it is fair to the producing States that they should enjoy the market, or the maximum production the reserves of such States will permit so long as such production is in keeping with proper conservation laws. It is folly to say that the greatest ultimate yield of petroleum will be enjoyed by the producing States and come to the great consuming portion of this country from our own markets, if production is permitted under scientific engineering advice, so as to not include shocking waste such as we have known to exist in the past, and in the same breath say that there shall be no protection to the producing States from the markets of foreign countries. This is true conservation, and this is what is best for our country as a whole. The provisions work both ways. If there is an unnecessary curtailment, or if there is a curtailment of production below what there should be produced, then the importation of the product can be permitted to a larger extent than otherwise.

Section 6 provides for voluntary industrial agreements. When the subjects to be covered in such agreements are read, it is hard to conceive of anyone objecting to any of it. They all suggest very pertinent and important phases of the petroleum industry in which the entire country is interested. As has been aptly said by one prominent member of our committee, this provision adopts, to an extent, the theory of the National Recovery Act, but brings about the genuine purposes thereof through voluntary action instead of by government fiat. It is true that such agreements, when approved, shall exempt the parties thereto from the provisions of the antitrust laws. The agreements must cover the subjects set forth in section 6 and be in the public interest, and, furthermore, have the approval, with the right of withdrawal thereof, of the President of the United States. The agreements must provide for adequate maximum wages for employees and for the maintenance of fair maximum hours of labor for employees. They are totally voluntary with no penalties for the violation thereof to be imposed by the Federal Government.

The remainder of the bill briefly embodies necessary administrative provisions and for an annual report of the Board to Congress.

The Committee on Interstate and Foreign Commerce respectfully recommend that H. R. 9053, as amended by the committee, do pass.

## MINORITY VIEWS

We, the undersigned members of the Committee on Interstate and Foreign Commerce, are opposed to the provision in the bill H. R. 9053 relating to the establishment of a Petroleum Administrative Board. It means another board with the usual consequences and additional expense and is, in our opinion, wholly unnecessary. All necessary work that the bill proposes to have the Board do is now done by the Bureau of Mines in the Department of the Interior, or can be done by it with little, if any, addition to its personnel.

We are opposed also to the provisions of the bill relating to voluntary agreements between those in the industry and making such agreements, when approved by the President, exempt from the provisions of the antitrust laws of the United States. Our experience with a similar provision in the National Industrial Recovery Act and its application to the codes was not such as to commend its application to the petroleum industry.

John G. Cooper.
Carl E. Mapes.
Pehr G. Holmes.
Schuyler Merritt.

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[Public—No. 145—75th Congress]

[Chapter 335—1st Session]

[S. 790]

AN ACT To continue in effect until June 30, 1939, the Act entitled "An Act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes," approved February 22, 1935

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That section 13 of the Act entitled "An Act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes", approved February 22, 1935, is amended by striking out "June 16, 1937" and inserting in lieu thereof "June 30, 1939".

Approved, June 14, 1937.

[H. Rept. No. 817, 75th Cong., 1st sess.]

The Committee on Interstate and Foreign Commerce, to whom was referred the bill (H. R. 5366) to repeal section 13 of the act entitled "An act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes", approved February 22, 1935, having considered and amended the same, report thereon with a recommendation that it pass with the following amendments:

Page 1, line 8, strike out "hereby repealed" and insert in lieu thereof the following: "amended by striking out 'June 16, 1937' and inserting in lieu thereof 'June 30, 1939'."

Amend the title so as to read: "An act to continue in effect until June 30, 1939, the Act entitled 'An act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes', approved February 22, 1935."

The bill has the approval of the Interstate Commerce Commission and the Interior Department, as will appear by the letters attached.

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INTERSTATE COMMERCE COMMISSION,
*Washington, March 24, 1937.*

Hon. CLARENCE F. LEA,
*Chairman, Committee on Interstate and Foreign Commerce,*
*House of Representatives.*

MY DEAR MR. CHAIRMAN: The chairman of the Commission has referred to our legislative committee your communication of March 9, 1937, requesting comments on H. R. 5366, introduced by Congressman Dies "to repeal section 13 of the act entitled 'An act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State laws, and for other purposes', approved February 22, 1935." This bill has had the careful consideration of the legislative committee, and I am authorized to submit the following comments in its behalf.

The substance of H. R. 5366 is indicated by its title. Section 13 of the act of February 22, 1935, is in one sentence reading, "This act shall cease to be in effect on June 16, 1937." Thus the bill changes the act of February 22, 1935, from temporary into permanent legislation. The act in question is one regulating the oil industry rather than transportation, and neither enlarges nor reduces nor affects the duties of this Commission under the various statutes it administers. From our point of view we have no objection to it, and we have no information which would enable us otherwise to give helpful advice in regard to it.

Respectfully submitted.

JOSEPH B. EASTMAN,
*Chairman, Legislative Committee.*

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THE SECRETARY OF THE INTERIOR,
*Washington, March 19, 1937.*

Hon. CLARENCE F. LEA,
*House of Representatives.*

MY DEAR MR. LEA: Replying to your letter of March 9, 1937, requesting a report on H. R. 5366, proposing to make permanent the law of February 22, 1935, which regulates interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law:

By giving strong support to the oil and gas conservation laws of the oil-producing States, the law of February 22, 1935, generally known as the Connally Act, has contributed materially to the advances made during the past few years in the prevention of avoidable physical waste in oil and gas production and to the resulting increased ultimate recovery of oil.

By eliminating contraband oil products from interstate commerce, the law has been one of the principal factors which have made it possible for nearly all independent and nonintegrated petroleum refiners to operate without incurring the substantial losses which threatened their existence immediately prior to the enactment of that legislation.

The law also has removed one of the most persistent elements in the vicious "price wars" which were prevalent prior to the enactment of the legislation and which threatened the existence in business of numerous independent retailers of petroleum products.

The law has made this contribution to the conservation of the Nation's oil and gas resources and to the economic stability of the petroleum industry without causing any material increase in the retail prices, ex taxes, of gasoline and other petroleum products.

The law has been supported with uniform success in the Federal courts in Texas and Louisiana.

In administering this law during the last 2 years, I have received full cooperation from the oil and gas conservation authorities of the several States and from the petroleum industry.

The need for the conservation of the Nation's oil and gas resources is of equal importance in periods of scarcity as in periods of excess supply and, in my opinion the legislation which supports the State oil and gas conservation laws should be made permanent by eliminating section 13 of the law of February 22, 1935.

The Bureau of the Budget has advised that it has no objection to the enactment of S. 790, a like bill introduced in the United States Senate by Senator Tom Connally. Hearings on S. 790 were held on February 12, 15, 16, and 17, before a subcommittee of the Committee on Finance of the United States Senate.

The enactment of H. R. 5366 is recommended.

Sincerely yours,

Charles West,
*Acting Secretary of the Interior.*

### CHANGES IN EXISTING LAW

In compliance with paragraph 2a of rule XIII of the Rules of the House of Representatives, section 13 of the act of February 22, 1935, proposed to be repealed by the bill as introduced is set forth below, and, for the information of the House, the change proposed to be made in such section by the bill as reported is shown by enclosing the matter to be omitted in black brackets and printing the new matter in italics.

"Sec. 13. This act shall cease to be in effect on [June 16, 1937] *June 30, 1939.*"

This bill was considered by a subcommittee and hearings were conducted thereon. As the bill, in the form amended by the committee, presents solely the question as to whether Public Law No. 14, Seventy-fourth Congress, which was S. 1190, shall become permanent law or extended for a temporary period beyond its present expiration date, June 16, 1937, and that question cannot be intelligently met without knowledge as to what the law in question is, we set forth at this point in the report Public Law No. 14:

"[Public—No. 14—74th Congress]

"[S. 1190]

"AN ACT To regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That it is hereby declared to be the policy of Congress to protect interstate and foreign commerce from the diversion and obstruction of, and the burden and harmful effect upon, such commerce caused by contraband oil as herein defined, and to encourage the conservation of deposits of crude oil situated within the United States.

"Sec. 2. As used in this Act—

"(1) The term 'contraband oil' means petroleum which, or any constituent part of which, was produced, transported, or withdrawn from storage in excess of the amounts permitted to be produced, transported, or withdrawn from storage under the laws of a State or under any regulation or order prescribed thereunder by any board, commission, officer, or other duly authorized agency of such State, or any of the products of such petroleum.

"(2) The term 'products' or 'petroleum products' includes any article produced or derived in whole or in part from petroleum or any product thereof by refining, processing, manufacturing, or otherwise.

"(3) The term 'interstate commerce' means commerce between any point in a State and any point outside thereof, or between points within the same State but through any place outside thereof, or from any place in the United States to a foreign country, but only insofar as such commerce takes place within the United States.

"(4) The term 'person' includes an individual, partnership, corporation, or joint-stock company.

"SEC. 3. The shipment or transportation in interstate commerce from any State of contraband oil produced in such State is hereby prohibited. For the purposes of this section contraband oil shall not be deemed to have been produced in a State if none of the petroleum constituting such contraband oil, or from which it was produced or derived, was produced, transported, or withdrawn from storage in excess of the amounts permitted to be produced, transported, or withdrawn from storage under the laws of such State or under any regulation or order prescribed thereunder by any board, commission, officer, or other duly authorized agency of such State.

"SEC. 4. Whenever the President finds that the amount of petroleum and petroleum products moving in interstate commerce is so limited as to be the cause, in whole or in part, of a lack of parity between supply (including imports and reasonable withdrawals from storage) and consumptive demand (including exports and reasonable additions to storage) resulting in an undue burden on or restriction of interstate commerce in petroleum and petroleum products, he shall by proclamation declare such finding, and thereupon the provisions of section 3 shall be inoperative until such time as the President shall find and by proclamation declare that the conditions which gave rise to the suspension of the operation of the provisions of such section no longer exist. If any provision of this section or the application thereof shall be held to be invalid, the validity or application of section 3 shall not be affected thereby.

"SEC. 5. (a) The President shall prescribe such regulations as he finds necessary or appropriate for the enforcement of the provisions of this Act, including but not limited to regulations requiring reports, maps, affidavits, and other documents relating to the production, storage, refining, processing, transporting, or handling of petroleum and petroleum products, and providing for the keeping of books and records, and for the inspection of such books, and records and of properties and facilities.

"(b) Whenever the President finds it necessary or appropriate for the enforcement of the provisions of this act he shall require certificates of clearance for petroleum and petroleum products moving or to be moved in interstate commerce from any particular area, and shall establish a board or boards for the issuance of such certificates. A certificate of clearance shall be issued by a board so established in any case where such board determines that the petroleum or petroleum products in question does not constitute contraband oil. Denial of any such certificate shall be by order of the board, and only after reasonable opportunity for hearing. Whenever a certificate of clearance is required for any area in any State, it shall be unlawful to ship or transport petroleum or petroleum products in interstate commerce from such area unless a certificate has been obtained therefor.

"(c) Any person whose application for a certificate of clearance is denied may obtain a review of the order denying such application in the United States District Court for the district wherein the board is sitting by filing in such court within thirty days after the entry of such order a written petition praying that the order of the board be modified or set aside, in whole or in part. A copy of such petition shall be forthwith served upon the board, and thereupon the board shall certify and file in the court a transcript of the record upon which the order complained of was entered. Upon the filing of such transcript, such court shall have jurisdiction to affirm, modify, or set aside such order, in whole or in part. No objection to the order of the board shall be considered by the court unless such objection shall have been urged before the board. The finding of the board as to the facts, if supported by evidence, shall be conclusive. The judgment and decree of the court shall be final, subject to review as provided in sections 128 and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 225 and 347).

"SEC. 6. Any person, knowingly violating any provision of this Act or any regulation prescribed thereunder shall upon conviction be punished by a fine of not to exceed $2,000 or by imprisonment for not to exceed six months, or by both such fine and imprisonment.

"SEC. 7. (a) Contraband oil shipped or transported in interstate commerce in violation of the provisions of this Act shall be liable to be proceeded against in any district court of the United States within the jurisdiction of which the same may be found, and seized for forfeiture to the United States by a process of libel for condemnation; but in any such case the court may in its discretion, and under such terms and conditions as it shall prescribe, order the return of such contraband oil to the owner thereof where undue hardship would result from such forfeiture. The proceedings in such cases shall conform as nearly as may be to proceedings in rem in admiralty, except that either party may demand a trial by jury of any issue of fact joined in any such case, and all such proceedings shall be at the suit of and in the name of the United States. Contraband oil forfeited to the United States as provided in this section shall be used or disposed of pursuant to such rules and regulations as the President shall prescribe.

"(b) No such forfeiture shall be made in the case of contraband oil owned by any person (other than a person shipping such contraband oil in violation of the provisions of this Act) who has with respect to such contraband oil a certificate of clearance which on its face appears to be valid and to have been issued by a board created under authority of section 5, certifying that the shipment in question is not contraband oil, and such person had no reasonable ground for believing such certificate to be invalid or to have been issued as a result of fraud or misrepresentation of fact.

"SEC. 8. No common carrier who shall refuse to accept petroleum or petroleum products from any area in which certificates of clearance are required under authority of this Act, by reason of the failure of the shipper to deliver such a certificate to such carrier, or who shall refuse to accept any petroleum or petroleum products when having reasonable ground for believing that such petroleum or petroleum products constitute contraband oil, shall be liable on account of such refusal for any penalties or damages. No common carrier shall be subject to any penalty under section 6 in any case where (1) such carrier has a certificate of clearance which on its face appears to be valid and to have been issued by a board created under authority of section 5, certifying that the shipment in question is not contraband oil, and such carrier had no reasonable ground for believing such certificate to be invalid or to have been issued as a result of fraud or misrepresentation of fact, or (2) such carrier, as respects any shipment originating in any area where certificates of clearance are not required under authority of this Act, had no reasonable ground for believing such petroleum or petroleum products to constitute contraband oil.

"SEC. 9. (a) Any board established under authority of section 5, and any agency designated under authority of section 11, may hold and conduct such hearings, investigations, and proceedings as may be necessary for the purposes of this Act, and for such purposes those provisions of section 21 of the Securities Exchange Act of 1934 relating to the administering of oaths and affirmations, and to the attendance and testimony of witnesses and the production of evidence (including penalties), shall apply.

"(b) The members of any board established under authority of section 5 shall be appointed by the President, without regard to the civil-service laws but subject to the Classification Act of 1923, as amended; and any such board may appoint, without regard to the civil-service laws but subject to the Classification Act of 1923, as amended, such employees as may be necessary for the execution of its functions under this Act.

"SEC. 10. (a) Upon application of the President, by the Attorney General, the United States District Courts shall have jurisdiction to issue mandatory injunctions commanding any person to comply with the provisions of this Act or any regulation issued thereunder.

"(b) Whenever it shall appear to the President that any person is engaged or about to engage in any acts or practices that constitute or will constitute a violation of any provision of this Act or of any regulation thereunder, he may in his discretion, by the Attorney General, bring an action in the proper United States District Court to enjoin such acts or practices, and upon a proper showing a permanent or temporary injunction or restraining order shall be granted without bond.

"(c) The United States District Courts shall have exclusive jurisdiction of violations of this Act or the regulations thereunder, and of all suits in equity and actions at law brought to enforce any liability or duty created by, or to enjoin any violation of, this Act or the regulations thereunder. Any criminal proceeding may be brought in the district wherein any act or transaction constituting the violation occurred. Any suit or action to enforce any liability or duty created by this Act or regulations thereunder, or to enjoin any violation of this Act or any regulations thereunder, may be brought in any such district or in the district wherein the defendant is found or is an inhabitant or transacts business, and process in such cases may be served in any other district of which the defendant is an inhabitant or wherever the defendant may be found. Judgments and decrees so rendered shall be subject to review as provided in sections 128 and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 225 and 347).

"SEC. 11. Wherever reference is made in this Act to the President such reference shall be held to include, in addition to the President, any agency, officer, or employee who may be designated by the President for the execution of any of the powers and functions vested in the President under this Act.

"SEC. 12. If any provision of this Act, or the application thereof to any person or circumstance, shall be held invalid, the validity of the remainder of the Act and the application of such provision to other persons or circumstances shall not be affected thereby.

"SEC. 13. This Act shall cease to be in effect on June 16, 1937.

"Approved, February 22, 1935."

The aforegoing temporary law, known as the Connally Act, had its birth as to the purpose thereof, in the National Industrial Recovery Act, being section 9–C thereof. This section was declared unconstitutional by the Supreme Court in the *Panama* and *Amazon cases*, decided on January 7, 1935, and reported in 293 United States 388. The question as to whether Congress can legally, under the interstate clause of the Constitution, prohibit shipments in interstate commerce, such as provided in the bill before us, was not determined by the Supreme Court in these cases. The sole reason for the rejection of 9–C being the invalid delegation of authority by Congress to the Executive. The existing law, which we now recommend be extended to June 30, 1939, it is believed meets the objections raised by the Supreme Court to the original law, in that a definite standard is laid down by the Congress and the law applied without any preliminary finding or declaration by the Executive as a prerequisite thereto. This is the principal change made by the last Congress followng the action of the Supreme Court in the cases involving the constitutionality of section 9–C of the National Industrial Recovery Act.

In 1933 the petroleum industry was adversely affected, like all industry, and with the price of crude oil dropping in many places as low as 10 cents per barrel there followed in the flush fields, and especially in the great east Texas fields, an almost total disregard for proration orders, and what was claimed to be decisions as to the production ability of such fields based on sound conservation theories. Producers receiving less than cost for their product, and having within their grasp the mere turning of a faucet to obtain unlimited quantities of a resource of such economic value, resorted to almost every conceivable means to defeat the effort of the States to conserve this natural resource. The production of oil in excess of the amount allowed to be produced by State order takes place, to some extent, at all times and does today, but it reached such outrageous proportions in 1934 that "hot oil" (as the quantity produced in violation of State law is termed) became the concern of not only the State within which production took place, but the Nation as a whole. The small producing States where the pumping wells prevail were concerned, because they could not compete with this great amount of excess cheap oil produced below any figure which they could even begin to meet. The authority of the State concerned was challenged and a break-down of their enforcement machinery—due in part to conditions beyond their control—caused a bad moral situation. From a national standpoint it was claimed, and we think rightfully so, that this great resource, limited in quantity and indispensable to the functioning of our Government, both in war and peace time, was being extravagantly wasted and all conceded theories of sound conservation were being abused if not ignored. There were those who advocated, because of the seriousness of the situation, the virtual regimentation of the great petroleum industry, now the second largest in the country, within the powers and control of the Federal Government. In fact, legislation presented went so far as to extend such control to the actual dictation of the Federal Government of almost every phase of the industry's activities. In lieu of the enactment of such legislation, Congress in 1934 authorized an investigation of the petroleum industry, and there was appointed for that purpose a committee, the personnel of which was the same as the subcommittee which considered this bill.

The hearings and report by this special committee have long since been exhausted because of the demand therefor. The investigation covered largely the technical side of petroleum—that is, as near as could be determined—the status of the known reserves in the country, methods of production, refining, transportation, and marketing, and the general public interest involved therein.

Recognizing that production of petroleum, because of the law of capture, and without any determination by the courts as to whether it lies within the power of the Federal Government to legislate even upon the subject of production in order that waste of such natural resource be prevented, as a committee, we gave encouragement to the Governors and other representatives of the oil-producing States to the formation of an interstate compact. As is known, such a compact was entered into by Oklahoma, Texas, California, New Mexico, Kansas, Illinois, and Colorado, and later ratified by the Seventy-fourth Congress. As the compact in question expires September 1937, it is our information that a renewal of that document is in the making and will be presented to the present Congress at a later date. For the information of the House, the consent of Congress as referred to is found in Public Resolution 64 of the Seventy-fourth Congress. It was further determined that due to the ease with which the proration orders could be violated and the difficulty from a legal standpoint for the States to prohibit shipments in interstate commerce of oil so produced, that the purposes and ideas behind the Connally Act—that is, 9-C of the National Recovery Act—were for a temporary period at least sound and advisable. This committee therefore recommended in February 1935 the enactment of the Connally Act for a period of 2 years to expire on June 16, 1937.

Later, H. R. 9053, reported to the House in August 1935, containing as it did, with some disagreement, what might be termed the final report of the special committee of 1934, transferred the administration of the Connally bill to the board established therein. The committee again at that time kept the Connally bill in effect for a temporary period only. This bill, while it did not pass—with the exception of the recommendation for a new agency of the Government, now found because of the administration of the present Petroleum Conservation Division possibly inadvisable—might well be considered as a permanent policy of the Government dealing with the petroleum industry.

The law which this bill extends applies particularly to the five States of Kansas, Louisiana, New Mexico, Oklahoma, and Texas, which in the aggregate produce about 75 percent of the national oil output and each of which has enacted State laws whereby the production of crude oil may be regulated so as to prevent waste. The Connally law will not apply in the remaining oil-producing States until such time as said States have adopted similar regulatory legislation. It does not determine the amount of oil which may be produced in the United States or from any State or from the fields and wells within a State. Each of the five States at present authorized by State law to do so determines for itself the amount of oil which currently may be produced without waste from the fields and wells within the State and, in doing so, takes account of all available and relative information with respect to the demand for oil, on the basis that production in excess of demand may in itself lead to waste. The existing law aids the States in the enforcement of these policies, by prohibiting the use of the facilities of interstate commerce in the transportation of such excess oil. Experience prior to the adoption of the existing procedure demonstrated that oil produced in violation of State law found its principal market in interstate commerce.

Although the operation of the present law, as stated in letter from Secretary Ickes (printed in this report), has been of material benefit to the independent petroleum refiners and the independent petroleum retailers, evidence presented to the committee indicates that its principal merit lies in the support which it gives to the State oil and gas conservation laws. Noteworthy examples of the benefits which will accrue to the public from such support of State conservation laws were presented to the committee. For example, the continuation of the present State regulatory measures in the east Texas field and the support given thereto by the Federal Government under the present law are expected to result in an increased recovery of oil which, according to minimum estimates, may be equal to the quantity of oil which might result from the discovery of 60 new average-sized oil fields.

The law provides that when the President finds it necessary or appropriate for the enforcement of the provisions of the act, he shall require certificates of clearance, or tenders, for petroleum and petroleum products moving in interstate commerce from any particular area and shall establish a board for the issuance of such certificates. During the 2 years in which the law has been operative, it has been found necessary to require certificates of clearance from but one area, that being the east Texas oil field. The importance of this field as a future source of oil supply to the Nation is shown by the fact that it produces nearly as much as the aggregate production of all of the wells in Louisiana, Kansas, and New Mexico, and at the time of its discovery contained more than one-fourth of the oil reserves of the entire United States. The Federal Tender Board operating in that area issues about 6,000 certificates of clearance annually, involving about 222,000,000 barrels of petroleum and petroleum products, at a cost of about one-tenth of a cent per barrel.

A report of the Tyler, Tex., branch office of the Department of Justice shows that, up to December 31, 1936, the Government instituted 222 criminal prosecutions directly and indirectly involving the Connally law, and as of that date had obtained 176 favorable decisions in said cases and no unfavorable deciisons. There were instituted also 26 civil cases directly and indirectly involving the Connally law, in which the Government was successful in 24 of the cases. Out of a total of 248 criminal and civil cases, the Government has been successful in 231, unsuccessful in 2, and has pending 15. The constitutionality of the act has been sustained in the United States District Courts for the Southern District of Texas, the Eastern District of Texas, and the Western District of Louisiana, and has been upheld by the Circuit Court of Appeals for the Fifth Circuit in three cases.

The operation of the existing law has had the further desirable effect of permitting the Federal Government, through the agency established by the President under the law to keep in constant touch with the petroleum industry in a more intimate way than would otherwise be the case. We regard this as extremely important in view of the fact that the production of oil has increased in the last 3 years approximately 40 percent, and yet new discoveries have not increased our known reserves over that of 3 years ago to the point that would justify such a large increase in production. In other words, if, as some feel, the reserves of petroleum said to exist 3 years ago would be exhausted in approximately 15 years to meet the demand at that time, then with the large increase in demand at this time without a corresponding addition to our reserves, the concern of the States enjoying the possession of this resource and the policy of production pursued by them becomes a concern of the National Government also. The bill before us, identical with S. 790 (the Connally bill), which has passed the Senate, makes the existing law permanent.

The committee recommends an amendment extending the law to June 30, 1939. We do this for numerous reasons. While the law is in aid of all States having conservation statutes, it has functioned solely in east Texas and the large resources of that State make the statutes of the State of Texas of principal concern. The Texas conservation law is temporary and expires September 1, 1939. It was testified in the hearings by a former chairman, who represented the Railroad Commission of Texas in the hearings; that if this law was not extended the problem could be handled by the State. The committee doubts the entire accuracy of this statement, but is strongly of the opinion that the commendable improvement which has taken place in the east Texas field in the past 3 years and the higher respect for the proration orders of the State commission, evidenced by the scarcity of excess production, might result at a later date in such a statement being justified. The present law has been criticized by some independent jobbers who claim that it has curtailed production and created a monopoly resulting in price fixing and the establishment of margins too low for the little independent jobber to operate. It was admitted, however, in the hearings by those taking this position that litigation now pending in which violations of the antitrust law is the basis, because of price-fixing tactics, was encouraged and supported by their group and covered to their mind the objections which they presented to this bill. In other words, the amendments suggested by them were not germane to this legislation and were really violation of other law. Without commenting on this litigation we feel that the determination of that case is important before this law is made permanent. The interstate oil compact pledges the States as parties thereto to the enactment of sound conservation and waste-prevention statutes. This compact expires September 1, 1937. The committee believes this presents an additional reason for the present law not being made permanent.

It is important, of course, to know the expense of the administration of this act. Excise taxes on oil production and refining imposed originally for the purpose of covering the cost of petroleum administration, amounted to $1,237,000 for the 1936 fiscal year. For the months from July 1936 to March 1937 the tax collection has totaled $647,000. This revenue must in fairness be claimed by the board administering the law before us. It is to the credit of the Interior Department to be able to state that instead of asking Congress for the entire amount so collected they have expended less than $300,000 a year for the total expense of carrying out the provisions of the present law. In other words, the revenue derived from existing taxes for the purposes of the present law amounts to over four times the sum expended, so that from an expense standpoint it is a profitable venture for the Government. We have little doubt that should this law not be extended there would be a request for the repeal of the present excise tax of one twenty-fifth of a cent on produced and also on oil refined.

This bill has the support of the Secretary of the Interior which Department administers the petroleum law, the Railroad Commission of the State of Texas, other State officials and boards, the Western Petroleum Refining Association, the American Bar Association, the Independent Petroleum Association, the Independent Association of Oil Field Workers, etc., and others found in the hearings.

It is strongly felt that the present law should not be made permanent at this time.

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[PUBLIC—No. 158—76TH CONGRESS]

[CHAPTER 250--1ST SESSION]

[S. 1302]

AN ACT To continue in effect until June 30, 1942, the Act entitled "An Act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petrolum and its products produced in violation of State law, and for other purposes," approved February 22, 1935, as amended

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That section 13 of the Act entitled "An Act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes," approved February 22, 1935, as amended by the Act approved June 14, 1937 (50 Stat. 257), is further amended so as to read:

"SEC. 13. This Act shall cease to be in effect on June 30, 1942."

Approved, June 29, 1939.

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[H. Rept. No. 807, 76th Cong., 1st sess.]

The Committee on Interstate and Foreign Commerce to whom was referred the bill (S. 1302) to make permanently effective the act entitled "An act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes," approved February 22, 1935, as amended, and for other purposes, having considered the same, report favorably thereon with an amendment and recommended that the bill as amended do pass.

The amendment is as follows:

Page 1, line 8, strike out "amended, is hereby repealed." and insert in lieu thereof the following: "amended by the Act approved June 14, 1937 (50 Stat. 257), is further amended so as to read:

" 'SEC. 13. This act shall cease to be in effect on June 30, 1942.' "

Page 2, strike out all of section 2 of the bill, lines 1 to 18, inclusive.

Amend the title so as to read: "A bill to continue in effect until June 30, 1942, the act entitled 'An act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes,' approved February 22, 1935, as amended."

Under authority of House Resolution 441, Seventy-fourth Congress, your committee was authorized to direct and investigate (1) the production, importation, storage, transportation, refining, purchase, and sale of petroleum and its products for the purpose of determining whether there is an excessive supply of petroleum and its products; whether such excessive supply, if it exists, injuriously affects commerce in petroleum and its products and has the effect of rendering unprofitable the operation of wells of small but settled production and will cause their abandonment before the maximum economic yield is obtained; whether premature extraction of petroleum from natural resources, induced by absence of restrictions upon the quantity which may move in commerce, results in waste and inferior uses; whether restrictions should be placed upon the quantities of petroleum and its products which may move in commerce when an excessive supply exists, and, if so, whether such restrictions should regulate and coordinate commerce in petroleum and its products among the several States and with foreign nations, with fair and equitable apportionment among the States and among different operators and sources of supply; and whether commerce in petroleum and its products is of such a nature that it may be regarded as a unit for the purpose of establishing quotas irrespective of whether transactions are interstate or intrastate, or whether exportation or importation is involved; and (2) all other questions in relation to the subject of regulating commerce in petroleum and its products.

The investigation ordered in this resolution was conducted by a subcommittee, and after a most thorough and comprehensive study your committee reported the results thereof to the House (Rept. No. 2, 74th Cong., Jan. 3, 1935).

Reading of this report and the hearings before the subcommittee is recommended to those interested in legislation pertaining to petroleum and associated subjects.

Because of the existence of section 9 of the National Industrial Recovery Act, which section attempted to prohibit the transportation in interstate commerce of petroleum and its products, produced or withdrawn from storage in excess of the amount permitted to be produced or withdrawn from storage by any State law or valid regulation or order prescribed thereunder, by any board, commission, officer, or other duly authorized agency of the State, that subject, which is the question before us in this bill, occupied a prominent place in the investigation of 1934. Following the decision of the Supreme Court in declaring section 9 of the National Recovery Act unconstitutional because it contained an invalid delegation of legislative power by Congress to the Executive (*Panama-Amazon cases*, 293 U. S. 383), the original Connally bill was introduced and passed in the Seventy-fourth Congress (Public Law 14, 74th Cong., 1st sess. Senate bill 1190).

Your committee conducted hearings on this subject during the Seventy-fourth Congress and submitted a unanimous report for the adoption of the original Connally bill (Rept. 148, 74th Cong., Feb. 14, 1935). That report reads in part:

"In S. 1190, as amended, Congress declares in no uncertain terms that such shipments, or transportation, in interstate commerce as defined therein, is prohibited, and violations of such Federal law is punishable in the manner prescribed. Immediately upon the passage of this act, therefore, shipments in interstate commerce of petroleum and petroleum products, as defined, become a violation of the law, and there is no delegation of authority to the President to determine anything before such law would become operative. There is a proviso, however, which is inserted for one controlling reason. As the bill passed the Senate, provisions of State law as to quantity of petroleum and its products which might legally be shipped in interstate commerce, furnished the sole guide for Federal action. In extending support to the oil-producing States, and accepting the decision of State law as to the quantity of production, this right possessed by the State must not be abused to the detriment of the consuming public. Some members of the committee felt that without the Senate bill being changed the agency of the Federal Government established as support to the States would be limited in the application of the law to the quantity of this resource, which could leave the producing sections of the country and cross State lines, exclusively be State law, and that that privilege might be abused. Other members of the committee did not feel that there was an occasion for alarm to this extent, because production in the producing States could not by law be curtailed to a point which the court would permit, if it violated the principles established in adjudicated cases, that production of crude oil could not be limited by State law in exercise of the policy power of the States, below a point that would be construed as a reasonable exercise of such power. In other words, limitation of production of petroleum under State law has been approved by the courts, and such limitation results from statutory law, having as its basis the prevention of waste and the conservation of this natural and limited resource.

"The committee inserted the proviso found in the bill, which does not arbitrarily delegate to the President the power to declare the law to be inoperative in his sole discretion, but only when he finds that the circumstances exist which are set forth in the statute. Congress says to the President in effect in the language of the amendment—'You are permitted to declare the existence of the facts by which this law shall be inoperative whenever you find that the supply of petroleum and the products thereof, moving in interstate commerce, is so limited as to cause in whole or in part a lack of parity between supply, including imports, and demand, including experts, resulting in an undue burden on, or restriction on, interstate commerce in petroleum and the products thereof.'

"Under this language the President, we assume, will require a factual basis for his finding, that factual finding being addressed to what limitation there is upon the supply moving in interstate commerce, and whether there is a lack of parity between such supply and demand. This is a definite requirement, a statement of circumstances and the imposition of conditions, all of which must be determined before the President can act. This power in the President presupposes a definite finding and a statement of the facts for the President's action before any such action is taken.

"The committee specifically point out that this bill provides for 'Federal control only as supporting the enforcement of the valid State law.' It leaves to the oil-producing States the entire authority to determine how much or how little oil shall be produced in their jurisdictions. The bill, in effect, says to the oil States:

" 'The United States prohibits entry into interstate commerce of oil produced in violation of your law, provided the amount is not so limited as to be against the greater interest of the Nation. In that case the prohibition will be suspended.'

"Another amendment of importance is one requiring that 'contraband, or hot oil' seized under violation of this bill be forfeited to the United States. The amendment is fair and constitutional. Every case might not justify the forfeiture of petroleum or petroleum products seized in apprehending the violator of the law under the bill, and for those cases carrying mitigating circumstances due protection has been provided. In the case of the hard-boiled violator who ships, for instance, by boat, large quantities of easily designated 'hot' oil, we can see no reason when the agency of the Federal Government is required to apprehend such a violator and that violation, of course, against Federal law, that the property seized thereunder should not be forfeited to the Federal Government. It would be folly, in dealing with such a defendant, to impose a fine, the amount thereof being ridiculous as compared with the value of the cargo, to then turn around and deliver back to him the same goods which he had previously possessed in violation of the law and for which he had been convicted. It is hard to conceive of cases where an innocent shipper might be technically guilty for the violation of such law, but it would be harsh and unreasonable to not deliver back to him in the State of production, or under such other arrangements as the court might impose, property which would be useful and of value."

The original act being in effect, by its terms, for a period of 2 years only, and ceasing to be effective on June 16, 1937, the subject again had to be considered by your committee.

At that time, the results of the operation of the law, which had been in effect 2 years, were disclosed in further hearings held on H. R. 5366. Following consideration of the subject at that time, another unanimous report from your committee was submitted (Rept. 817, 75th Cong., 1st sess.) This report was filed on May 14, 1937, and extended Public Law 14, passed in 1935, to June 30, 1939.

It was recommended at that time the extension of the act of the Seventy-fourth Congress from June 16, 1937, to June 30, 1939. The following statement from the report of the Seventy-fifth Congress is applicable today, as then:

"In 1933 the petroleum industry was adversely affected, like all industry; and with the price of crude oil dropping in many places as low as 10 cents per barrel, there followed in the flush fields, and especially in the great east Texas fields, an almost total disregard for proration orders, and what was claimed to be decisions as to the production ability of such fields based on sound conservation theories. Producers receiving less than cost for their product and having within their grasp the mere turning of a faucet to obtain unlimited quantities of a resource of such economic value resorted to almost every conceivable means to defeat the effort of the States to conserve this natural resource. The production of oil in excess of the amount allowed to be produced by State order takes place to some extent at all times, and does today, but it reached such outrageous proportions in 1934 that "hot oil" (as the quantity produced in violation of State law is termed) became the concern of not only the State within which production took place but the Nation as a whole. The small producing States where the pumping wells prevail were concerned, because they could not compete with this great amount of excess cheap oil produced below any figure which they could even begin to meet. The authority of the State concerned was challenged, and a break-down of their enforcement machinery—due in part to conditions beyond their control—caused a bad moral situation. From a national standpoint, it was claimed, and we think rightfully so, that this great resource, limited in quantity and indispensable to the functioning of our Government, both in war and peacetime, was being extravagantly wasted, and all conceded theories of sound conservation were being abused, if not ignored.

"There were those who advocated, because of the seriousness of the situation, the virtual regimentation of the great petroleum industry, now the second largest in the country, within the powers and control of the Federal Government. In fact, legislation presented went so far as to extend such control to the actual dictation of the Federal Government of almost every phase of the industry's activities. In lieu of the enactment of such legislation, Congress in 1934 authorized an investigation of the petroleum industry, and there was appointed for that purpose a committee, the personnel of which was the same as the subcommittee which considered this bill.

"The hearings and report by this special committee have long since been exhausted because of the demand therefor. The investigation covered largely the technical side of petroleum—that is, as near as could be determined—the status of the known reserves in the country, methods of production, refining, transportation, and marketing, and the general public interest involved therein.

"Recognizing that production of petroleum, because of the law of capture, and without any determination by the courts as to whether it lies within the power of the Federal Government to legislate even upon the subject of production in order that waste of such natural resource be prevented, as a committee, we gave encouragement to the governors and other representatives of the oil-producing States to the formation of an interstate compact. As is known, such a compact was entered into by Oklahoma, Texas, California, New Mexico, Kansas, Illinois, and Colorado, and later ratified by the Seventy-fourth Congress.

"The law which this bill extends applies particularly to the five States of Kansas, Louisiana, New Mexico, Oklahoma, and Texas, which in the aggregate produce about 75 percent of the national oil output, and each of which has enacted State laws whereby the production of crude oil may be regulated so as to prevent waste. The Connally law will not apply in the remaining oil-producing States until such time as said States have adopted similar regulatory legislation. It does not determine the amount of oil which may be produced in the United States or from any State or from the fields and wells within a State. Each of the five States at present authorized by State law to do so determines for itself the amount of oil which currently may be produced without waste from the fields and wells within the State, and in doing so takes account of all available and relative information with respect to the demand for oil, on the basis that production in excess of demand may in itself lead to waste. The existing law aids the States in the enforcement of these policies by prohibiting the use of the facilities of interstate commerce in the transportation of such excess oil. Experience prior to the adoption of the existing procedure demonstrated that oil produced in violation of State law found its principal market in interstate commerce.

"Although the operation of the present law, as stated in letter from Secretary Ickes (printed in this report), has been of material benefit to the independent petroleum refiners and the independent petroleum retailers, evidence presented to the committee indicates that its principal merit lies in the support which it gives to the State oil and gas conservation laws. Noteworthy examples of the benefits which will accrue to the public from such support of State conservation laws were presented to the committee. For example, the continuation of the present State regulatory measure in the east Texas field and the support given thereto by the Federal Government under the present law are expected to result in an increased recovery of oil which, according to minimum estimates, may be equal to the quantity of oil which might result from the discovery of 60 new average-sized fields."

Your committee, having dealt so often and so intimately with the subject, in making this report finds its purposes best served by making reference to the numerous reports made in the past, hence the references found herein.

In the committee's report of 1937, this observation was made:

"The law provides that when the President finds it necessary or appropriate for the enforcement of the provisions of the act, he shall require certificates of clearance, or tenders, for petroleum and petroleum products moving in interstate commerce from any particular area and shall establish a board for the issuance of such certificates. During the 2 years in which the law has been operative, it has been found necessary to require certificates of clearance from but one area, that being the east Texas oil field. The importance of this field as a future source of oil supply to the Nation is shown by the fact that it produces nearly as much as the aggregate production of all of the wells in Louisiana, Kansas, and New Mexico, and at the time of its discovery contained more than one-fourth of the oil reserves of the entire United States. The Federal Tender Board operating in that area issues about 6,000 certificates of clearance annually, involving about 222,000,000 barrels of petroleum and petroleum products, at a cost of about one-tenth of a cent per barrel."

Bringing the foregoing to date, and showing the activities of the Tender Board in the east Texas field, the report to the committee disclosed that 6,942 applications for tenders were filed in the fiscal year ending June 30, 1938, of which number 4,992 were for 254,614,303 barrels of crude oil and 1950 were for 27,716,209 barrels of petroleum products (gasoline, fuel oil, natural gasoline, etc.), or a total of 282,303,512 barrels in all. It is interesting to note at this point that the total appropriation for the expense of the administration of this act for the last year was $285,000, which amounted to about one-tenth of a cent per barrel.

The foregoing is mentioned because, while this law is in aid of the States having conservation statutes, it is functioning solely in the east Texas field and the large oil resources of that State make the Texas statute of particular concern. The Texas law is temporary and expires September 1, 1939. Your committee were advised that further extension of the present temporary statute will be made effective in September of this year for an additional period. The Texas law, which this act is to support, not being permanent, continues as a temporary measure.

The bills considered by your committee were all submitted to the Department of Interior for comment, and the following letters, dealing with the subject at considerable length, rehearse much of the testimony which your committee might otherwise include in this report.

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Department of the Interior,
*Washington, April 26, 1939.*

Hon. William P. Cole,
*Chairman, Subcommittee of the Committee on
Interstate and Foreign Commerce, House of Representatives.*

My Dear Mr Cole: On March 13, in a letter reporting on H. R. 4547, identical with S. 1302, to Hon. Clarence F. Lea, chairman of the Committee on Interstate and Foreign Commerce, I recommended that the law of February 22, 1935, should be made permanent. As the hearings on this bill are being held Wednesday and Thursday of this week while I am to be out of town, I take this opportunity to address you and your committee concerning the permanence of this legislation. As I see the situation, there are at least three major reasons why the law should be made permanent.

The Department of the Interior for many years has had a continuing interest in oil conservation. Working in that direction since 1924, it has come to be of the opinion that the time has arrived when serious consideration should be given to more comprehensive legislation which should be built on the experience which the States, the Federal Government, and the industry have gained. The Connally law is legislation of proven value. It performs a basic function in the prevention of the movement of contraband oil in interstate and foreign commerce and should be considered as fundamental in any broader program of oil conservation in which the Federal Government may participate.

The States of Arkansas, Kansas, Louisiana, New Mexico, and Oklahoma have enacted permanent conservation legislation. Proposed conservation laws on a permanent basis are now being considered by the Legislatures of California, Michigan, and Illinois and it is expected that they will receive favorable consideration. These eight States, which have permanent laws or may soon enact them, produce 56 percent of the national output. Texas, which produces 40 percent, may soon make its law permanent. In view of the fact that these States with, or considering, oil-conservation laws produce about 96 percent of the petroleum of the United States, it appears reasonable to support them permanently with this Federal legislation. There should be no doubt in the minds of the State authorities that the Federal interest in the conservation of oil is a continuing interest and not a matter for speculation from one session of Congress to the next. The Congress should assure the States of the continuing Federal interest.

Although the problem of administration of temporary legislation as compared with permanent legislation may seem to be of minor consequence, the fact remains that efficient and understanding administration and permanent career-minded personnel make for better administration than a personnel that is constantly in doubt concerning whether it should use its training and experience in the administration of a temporary law or transfer to an organization that has greater security.

Sincerely yours,

HAROLD L. ICKES,
*Secretary of the Interior.*

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DEPARTMENT OF THE INTERIOR,
*Washington, March 14, 1939.*

Hon. CLARENCE F. LEA,
*Chairman, Committee on Interstate and Foreign Commerce,*
*House of Representatives.*

MY DEAR MR. CHAIRMAN: I have received your letter of January 23, with which you enclosed a copy of H. R. 2308 proposing to repeal the act approved February 22, 1935, as amended, generally known as the Connally Act, and on behalf of the Committee on Interstate and Foreign Commerce requested a report and any comment I might care to make on this measure.

Although petroleum is essential to our daily needs, it is a vital necessity to our national defense, not only to the military forces but to the civilian manufacturing and transportation facilities which support the Army and Navy. It is estimated currently that the demands for petroleum during such an emergency will require an additional supply of 800,000 barrels daily. Our oil reserves do not equal those of the rest of the world, but we consume annually more petroleum than the total of all of the other countries. On the basis of civilian needs alone, a continuation of that relationship will result in an oil scarcity in the United States before there is a corresponding shortage abroad. The need to provide petroleum for the national defense becomes increasingly important as we approach closer to that period of scarcity.

Six of the prinicpal oil-producing States—Arkansas, Kansas, Louisiana, New Mexico, Oklahoma, and Texas, which produce about 70 percent of the national output of crude oil—have enacted laws which authorize the regulation of oil and gas production in order to prevent waste and avoid discrimination. The Federal Government, through the act of February 22, 1935, as amended, supports the expressed policies of these States by prohibiting the shipment in interstate and foreign commerce of petroleum produced in excess of the amounts permitted by the authorities in these States. Three other States—California, Illinois, and Michigan, which produce 24 percent of the total—have similar legislation under consideration at current sessions of their legislatures. The Connally Act will apply to petroleum produced in these States, if legislation pending therein is enacted, but does not so apply at present.

This procedure is preventing waste and increasing the efficiency of oil production in the United States. Our petroleum supply is being maintained to an important degree by improvements in methods of production, which make possible an increased recovery of oil from our proven reserves. By making certain that we produce oil in the United States more efficiently and with a higher recovery factor than in other countries, our oil supply can be brought closer to a parity with the oil resources of the rest of the world and we can thus postpone the time when we will have to depend upon foreign supplies or alternative fuels at higher prices.

In brief, it is my opinion that the Connally Act, by giving strong support to the oil and gas conservation laws of the oil-producing States, has made a substantial contribution to the conservation of the oil and gas resources of the Nation. The Federal and State responsibilities in this respect have been coordinated without placing any undue burden upon the consumer of petroleum products. In fact, in the opinion of this Department, the consumer will continue to benefit if this program of making adequate supplies of oil available at reasonable prices is adopted as the permanent policy of the United States.

Accordingly, not only am I opposed to the repeal of the Connally Act but I favor its continuance along with the enactment by the Congress of more comprehensive legislation which will protect adequately our needs for oil for national defense and for the general welfare. It is recommended that H. R. 2308 be not enacted.

I have been advised by the Bureau of the Budget that there would be no objection by that office to the presentation of this report to your committee.

Sincerely yours,

E. K. Burlew,
*Acting Secretary of the Interior.*

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Department of the Interior,
*Washington, March 13, 1939.*

Hon. Clarence F. Lea,
*Chairman, Committee on Interstate and Foreign Commerce,*
*House of Representatives.*

My Dear Mr. Lea: I have received your letter of February 28 with which you enclosed a copy of H. R. 4547, a like bill to S. 1302, to make permanently effective the act approved February 22, 1935, as amended, generally known as the Connally Act, and requesting that I report thereon.

This law, which has now been in effect 4 years, has been a definite forward step toward the conservation of petroleum, an irreplaceable national resource, through cooperation between the oil-producing States and the Federal Government. As stated in the report of the National Resource Committee forwarded to the Congress by the President, February 15:

"The rank of petroleum as a source of energy, its vital importance in national defense, its vulnerability to destructive forces in exploitation, and its comparatively small reserve in comparison with its high rate of withdrawal place this commodity in a unique position among the natural resources."

A continuous stream of reasonably priced petroleum products is essential for the maintenance of the national defense and our economic structure. The consumption of gasoline, Diesel oil, fuel oil, and lubricating oil has become so commonplace that few people realize that all of the airplanes, virtually all of the automobiles, of which there are now about 30 million, a large number of locomotives, and virtually all of the United States merchant marine and Navy are driven by petroleum products. The industrial life of this country, including agriculture, our metropolitan centers and their suburban areas, our towns, large and small, are geared to the use of petroleum products. In our national defense, petroleum is not only vital to the military forces but to the civil and manufacturing and transportation facilities which support or supplement the Army and Navy. It is estimated that at current rates of consumption a national emergency would require an additional supply of 800,000 barrels of petroleum daily.

The proved oil reserve of the United States is not equal to that of the remainder of the world, but the annual consumption of petroleum in this country exceeds the total of all other countries. (United States percentage of world reserve, 50; of consumption, 60.) In other words we are pressing on our proved reserve of petroleum more than the rest of the world and we may consequently face an oil scarcity before there is a corresponding shortage abroad.

Six oil-producing States—Arkansas, Kansas, Louisiana, New Mexico, Oklahoma, and Texas—which produce about 70 percent of the national output of petroleum, have enacted laws authorizing the regulation of oil and gas production to prevent waste and to avoid discrimination. The Federal Government, through the Connally law, as amended, supports the expressed policies of these States by prohibiting the shipment in interstate and foreign commerce of petroleum produced in violation of the laws of these States. Three other States—California, Illinois, and Michigan—which in total produce 24 percent of the national output, have similar legislation under consideration and if such laws are passed the Connally Act would apply to petroleum produced in those States.

This procedure is preventing waste and increasing the efficiency of oil production in the United States. Our petroleum supply is being maintained to an important degree by improvements in methods of production, which make possible an increased recovery of oil from our proved reserves. By making certain that we produce oil in the United States more efficiently and with a higher recovery factor than in other countries, our oil supply can be brought closer to a parity with the oil resources of the rest of the world and we can thus postpone the time when we will have to depend upon foreign supplies or alternative fuels, both at higher prices.

In brief, it is my opinion that the Connally Act, by giving strong support to the oil and gas conservation laws of the oil-producing States, has made a substantial contribution to the conservation of the oil and gas resources of the Nation and also that the Federal and State responsibilities in this respect have been coordinated without placing any undue burden upon the consumer of petroleum products. In fact, I am convinced that the consumer will continue to benefit if the policy announced in the Connally Act of making adequate supplies of oil available at reasonable prices is adopted as permanent legislation of the United States.

Accordingly, I favor the continuance of the Connally Act as a step toward the protection of our needs for oil for the national defense and for the general welfare. The gains so far accomplished by some of the States and by the Federal Government should not be lost and future legislation should be built upon this foundation of State and Federal cooperation. I accordingly recommend that H. R. 4547 be passed.

I have been advised by the Bureau of the Budget that there would be no objection by that office to the presentation of this report to your committee.

Sincerely yours.

HAROLD L. ICKES,
*Secretary of the Interior.*

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Since the passage of the original act and the extension thereof, in the spring of 1937, the District Court of the Eastern District of the United States for the Southern District of Texas sustained the demurrers and motions to quash an indictment for the violation of the Connally Act. The indictment charged violations prior to the expiration date of June 16, 1937, and the basis of the demurrer was that the extension by Congress of the effect of the act for an additional 2-year period did not permit prosecution of violations alleged to have been committed prior to June 16, 1937. Because of this decision, the Senate included section 2 in the bill, although many doubted the necessity for such a provision. Since the bill reached the House, during consideration thereof by your committee, the Supreme Court of the United States (in *U. S.* v. *Powers and Allred*, No. 687, October term, 1938), in the first opinion delivered by Mr. Justice Douglas, reversed the Texas court. This makes it admittedly unnecessary for section 2 in the bill as it passed the Senate to be included and the committee has therefore stricken it out.

The opinion of Justice Douglas is printed in the hearings (p. 174) on this bill, and it is interesting to note that the Supreme Court, in the opinion referred to, makes this statement:

"This is an act designed to protect interstate and foreign commerce from the diversion and obstruction of, and the burden and harmfull effect upon, such commerce caused by contraband oil (as defined in the act) and to encourage the conservation of deposits of crude oil within the United States."

This quotation from the Supreme Court's decision is given because the committee believes all familiar with this subject are in agreement that the primary purpose of the Connally Act is to encourage conservation of our crude-oil deposits. This is in direct contradiction of the testimony heard by your committee from those appearing in opposition to this bill. In fact, with that part of the opposition testimony eliminated, that is, their statements that the Connally bill is not a conservation measure, very little is left.

With six of the principal oil-producing States—Arkansas, Kansas, Louisiana, New Mexico, Oklahoma, and Texas, which produce about 70 percent of the total output of the United States—enacting laws known as conservation statutes and regulating the production of oil to prevent the waste thereof, your committee feels that past experience presents very definite reasons for the Government to cooperate to the extent provided in this legislation.

While your committee is in sympathy with some of the arguments presented by the Secretary of the Interior in his letter of April 26, addressed to the chairman of the subcommittee, especially that paragraph dealing with the wisdom of having a permanent law instead of temporary legislation. it is felt that until the principal oil-producing States show a willingness to enact permanent conservation statutes, such as the enforcement of this legislation contemplates, Congress should continue cooperation on behalf of the Federal Government on a temporary basis only.

Every due consideration was given to the few witnesses appearing against this legislation and everyone asking to be heard was given an opportunity either to testify or insert a statement in the record. Without meaning to reflect upon the sincerity of those making up the opposition, it is felt that no constructive reasons for the discontinuance of this act have been advanced.

Your committee is unanimous in recommending the extension of the present law, not for a period of 2 years, as has been done on two occasions in the past, but for an additional period of 3 years, expiring on June 30, 1942.

### CHANGES IN EXISTING LAW

In compliance with paragraph 2a of rule XIII of the Rules of the House of Representatives, section 13 of the act of February 22, 1935, as it was amended by the act of June 14, 1937, which was proposed to be repealed by the bill as passed by the Senate is shown in roman; the change in this section proposed to be made by this bill as reported to the House is shown in italics.

Section 13 of the act as approved February 22, 1935:

"SEC. 13. This Act shall cease to be in effect on June 16, 1937."

Above section 13 as amended by the act approved June 14, 1937: "SEC. 13. This Act shall cease to be in effect on June 30, 1937."

Above section 13, as proposed to be amended by the reported bill: "SEC. 13. *This Act shall cease to be in effect on June 30, 1942.*"

For the information of the House there is set forth the complete text of the act of February 22, 1935, as follows:

"[Public, No. 14, 74th Cong., approved February 22, 1935 (49 Stat. 30)]

"AN ACT To regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That it is hereby declared to be the policy of Congress to protect interstate and foreign commerce from the diversion and obstruction of, and the burden and harmful effect upon, such commerce caused by contraband oil as herein defined, and to encourage the conservation of deposits of crude oil situated within the United States.

"SEC. 2. As used in this Act—

"(1) The term 'contraband oil' means petroleum which, or any constituent part of which, was produced, transported, or withdrawn from storage in excess of the amounts permitted to be produced, transported, or withdrawn from storage under the laws of a State or under any regulation or order prescribed thereunder by any board, commission, officer, or other duly authorized agency of such State, or any of the products of such petroleum.

"(2) The term 'products' or 'petroleum products' includes any article produced or derived in whole or in part from petroleum or any product thereof by refining, processing, manufacturing, or otherwise.

"(3) The term 'interstate commerce' means commerce between any point in a State and any point outside thereof, or between points within the same State but through any place outside thereof, or from any place in the United States to a foreign country, but only insofar as such commerce takes place within the United States.

"(4) The term 'person' includes an individual, partnership, corporation, or joint-stock company.

"SEC. 3. The shipment or transportation in interstate commerce from any State of contraband oil produced in such State is hereby prohibited. For the purposes of this section contraband oil shall not be deemed to have been produced in a State if none of the petroleum constituting such contraband oil, or from which it was produced or derived, was produced, transported, or withdrawn from storage in excess of the amounts permitted to be produced, transported, or withdrawn from storage under the laws of such State or under any regulation or order prescribed thereunder by any board, commission, officer, or other duly authorized agency of such State.

"SEC. 4 Whenever the President finds that the amount of petroleum and petroleum products moving in interstate commerce is so limited as to be the cause, in whole or in part, of a lack of parity between supply (including imports and reasonable withdrawals from storage) and consumptive demand (including exports and reasonable additions to storage) resulting in an undue burden on or restriction of interstate commerce in petroleum and petroleum products, he shall by proclamation declare such finding, and thereupon the provisions of section 3 shall be inoperative until such time as the President shall find and by proclamation declare that the conditions which gave rise to the suspension of the operation of the provisions of such section no longer exist. If any provision of this section or the application thereof shall be held to be invalid, the validity or application of section 3 shall not be affected thereby.

"SEC. 5. (a) The President shall prescribe such regulations as he finds necessary or appropriate for the enforcement of the provisions of this Act, including but not limited to regulations requiring reports, maps, affidavits, and other documents relating to the production, storage, refining, processing, transporting, or handling of petroleum and petroleum products, and providing for the keeping of books and records, and for the inspection of such books and records and of properties and facilities.

"(b) Whenever the President finds it necessary or appropriate for the enforcement of the provisions of this act he shall require certificates of clearance for petroleum and petroleum products moving or to be moved in interstate commerce from any particular area and shall establish a board or boards for the issuance of such certificates. A certificate of clearance shall be issued by a board so established in any case where such board determines that the petroleum or petroleum products in question does not constitute contraband oil. Denial of any such certificate shall be by order of the board and only after reasonable opportunity for hearing. Whenever a certificate of clearance is required for any area in any State, it shall be unlawful to ship or transport petroleum or petroleum products in interstate commerce from such area unless a certificate has been obtained therefor.

"(c) Any person whose application for a certificate of clearance is denied may obtain a review of the order denying such application in the United States District Court for the district wherein the board is sitting by filing in such court within thirty days after the entry of such order a written petition praying that the order of the board be modified or set aside, in whole or in part. A copy of such petition shall be forthwith served upon the board, and thereupon the board shall certify and file in the court a transcript of the record upon which the order complained of was entered. Upon the filing of such transcript, such court shall have jurisdiction to affirm, modify, or set aside such order, in whole or in part. No objection to the order of the board shall be considered by the court unless such objection shall have been urged before the board. The finding of the board as to the facts, if supported by evidence, shall be conclusive. The judgment and decree of the court shall be final, subject to review as provided in sections 128 and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 225 and 347).

"SEC. 6. Any person knowingly violating any provision of this Act or any regulation prescribed thereunder shall upon conviction be punished by a fine of not to exceed $2,000 or by imprisonment for not to exceed six months, or by both such fine and imprisonment.

"SEC. 7. (a) Contraband oil shipped or transported in interstate commerce in violation of the provisions of this Act shall be liable to be proceeded against in any district court of the United States within the jurisdiction of which the same may be found, and seized for forfeiture to the United States by a process of libel for condemnation; but in any such case the court may in its discretion, and under such terms and conditions as it shall prescribe, order the return of such contraband oil to the owner thereof where undue hardship would result from such forfeiture. The proceedings in such cases shall conform as nearly as may be to proceedings in rem in admiralty, except that either party may demand a trial by jury of any issue of fact joined in any such case, and all such proceedings shall be at the suit of and in the name of the United States. Contraband oil forfeited to the United States as provided in this section shall be used or disposed of pursuant to such rules and regulations as the President shall prescribe.

"(b) No such forfeiture shall be made in the case of contraband oil owned by any person (other than a person shipping such contraband oil in violation of the provisions of this Act) who has with respect to such contraband oil a certificate of clearance which, on its face, appears to be valid and to have been issued by a board created under authority of section 5, certifying that the shipment in question is not contraband oil, and such person had no reasonable ground for believing such certificate to be invalid or to have been issued as a result of fraud or misrepresentation of fact.

"SEC. 8. No common carrier who shall refuse to accept petroleum or petroleum products from any area in which certificates of clearance are required under authority of this Act, by reason of the failure of the shipper to deliver such a certificate to such carrier, or who shall refuse to accept any petroleum or petroleum products when having reasonable ground for believing that such petroleum or petroleum products constitute contraband oil, shall be liable on account of such refusal for any penalties or damages. No common carrier shall be subject to any penalty under section 6 in any case where (1) such carrier has a certificate of clearance which on its face appears to be valid and to have been issued by a board created under authority of section 5, certifying that the shipment in question is not contraband oil, and such carrier had no reasonable ground for believing such certificate to be invalid or to have been issued as a result of fraud or misrepresentation of fact, or (2) such carrier, as respects any shipment originating in any area where certificates of clearance are not required under authority of this Act, had no reasonable ground for believing such petroleum or petroleum products to constitute contraband oil.

"SEC. 9. (a) Any board established under authority of section 5, and any agency designated under authority of section 11, may hold and conduct such hearings, investigations, and proceedings as may be necessary for the purposes of this Act, and for such purposes those provisions of section 21 of the Securities Exchange Act of 1934 relating to the administering of oaths and affirmations, and to the attendance and testimony of witnesses and the production of evidence (including penalties), shall apply.

"(b) The members of any board established under authority of section 5 shall be appointed by the President, without regard to the civil-service laws but subject to the Classification Act of 1923, as amended; and any such board may appoint, without regard to the civil-service laws but subject to the Classification Act of 1923, as amended, such employees as may be necessary for the execution of its functions under this Act.

"SEC. 10. (a) Upon application of the President, by the Attorney General, the United States District Courts shall have jurisdiction to issue mandatory injunctions commanding any person to comply with the provisions of this Act or any regulation issued thereunder.

"(b) Whenever it shall appear to the President that any person is engaged or about to engage in any acts or practices that constitute or will constitute a violation of any provision of this Act or of any regulation thereunder, he may in his discretion, by the Attorney General, bring an action in the proper United States District Court to enjoin such acts or practices, and upon a proper showing a permanent or temporary injunction or restraining order shall be granted without bond.

"(c) The United States District Courts shall have exclusive jurisdiction of violations of this Act or the regulations thereunder, and of all suits in equity and actions at law brought to enforce any liability or duty created by, or to enjoin any violation of, this Act or the regulations thereunder. Any criminal proceeding may be brought in the district wherein any act or transaction constituting the violation occurred. Any suit or action to enforce any liability or duty created by this Act or regulations thereunder, or to enjoin any violation of this Act or any regulations thereunder, may be brought in any such district or in the district wherein the defendant is found or is an inhabitant or transacts business, and process in such cases may be served in any other district of which the defendant is an inhabitant or wherever the defendant may be found. Judgments and decrees so rendered shall be subject to review as provided in sections 128 and 240 of the Judicial Code, as amended (U. S. C., title 28, secs. 225 and 347).

"SEC. 11. Wherever reference is made in this Act to the President such reference shall be held to include, in addition to the President, any agency, officer, or employee who may be designated by the President for the execution of any of the powers and functions vested in the President under this Act.

"SEC. 12. If any provision of this Act, or the application thereof to any person or circumstance, shall be held invalid, the validity of the remainder of the Act and the application of such provision to other persons or circumstances shall not be affected thereby.

"SEC. 13. This Act shall cease to be in effect on June 16, 1937.

"Approved, February 22, 1935."

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[PUBLIC—NO. 145—75TH CONGRESS]

[CHAPTER 335—1ST SESSION]

[S. 790]

AN ACT To continue in effect until June 30, 1939, the Act entitled "An Act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes," approved February 22, 1935

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That section 13 of the Act entitled "An Act to regulate interstate and foreign commerce in petroleum and its products by prohibiting the shipment in such commerce of petroleum and its products produced in violation of State law, and for other purposes," approved February 22, 1935, is amended by striking out "June 16, 1937," and inserting in lieu thereof "June 30, 1939."

Approved, June 14, 1937.

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[PUBLIC RESOLUTION—NO. 57—75TH CONGRESS]

[CHAPTER 572—1ST SESSION]

[S. J. Res. 183]

JOINT RESOLUTION Consenting to an interstate oil compact to conserve oil and gas

*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled,* That the consent of Congress is hereby given to an extension and renewal for a period of two years from September 1, 1937, of the interstate compact to conserve oil and gas, executed in the city of Dallas, Texas, the 16th day of February 1935 by the representatives of the States of Oklahoma, Texas, California, and New Mexico, and thereafter recommended for ratification by the representatives of the States of Arkansas, Colorado, Illinois, Kansas, and Michigan, and subsequently ratified by the States of New Mexico, Kansas, Oklahoma, Illinois, Colorado, and Texas, which said compact was deposited in the Department of State of the United States, and thereafter such compact was, by the President, presented to the Congress and the Congress gave consent to such compact by H. J. Res. 407, approved August 27, 1935 (Public Resolution Numbered 64, Seventy-fourth Congress). The extended and renewed compact, executed in New Orleans, Louisiana, the 10th day of May 1937 by the representatives of the States of Oklahoma, Texas, Kansas, and New Mexico, and there recommended for ratification by representatives of the States of Oklahoma, Texas, Kansas, New Mexico, Illinois, and Colorado, and since ratified by the said States of Oklahoma, Texas, Kansas, New Mexico, Illinois, and Colorado, which extended and renewed compact has been deposited in the Department of State of the United States, and reads as follows:

"ARTICLE I

"This agreement may become effective within any compacting State at any time as prescribed by that State, and shall become effective within those states ratifying it whenever any three of the States of Texas, Oklahoma, California, Kansas, and New Mexico have ratified and Congress has given its consent. Any oil-producing State may become a party hereto as hereinafter provided.

"ARTICLE II

"The purpose of this compact is to conserve oil and gas by the prevention of physical waste thereof from any cause.

"ARTICLE III

"Each State bound hereby agrees that within a reasonable time it will enact laws, or if laws have been enacted, then it agrees to continue the same in force, to accomplish within reasonable limits the prevention of—

"(a) The operation of any oil well with an inefficient gas-oil ratio.

"(b) The drowning with water of any stratum capable of producing oil or gas, or both oil and gas in paying quantities.

"(c) The avoidable escape into the open air or the wasteful burning of gas from a natural-gas well.

"(d) The creation of unnecessary fire hazards.

"(e) The drilling, equipping, locating, spacing, or operating of a well or wells so as to bring about physical waste of oil or gas or loss in the ultimate recovery thereof.

"(f) The inefficient, excessive, or improper use of the reservoir energy in producing any well.

"The enumeration of the foregoing subjects shall not limit the scope of the authority of any State.

### "Article IV

"Each State bound hereby agrees that it will, within a reasonable time, enact statutes, or if such statutes have been enacted then that it will coninue the same in force, providing in effect that oil produced in violation of its valid oil and/or gas conservation statutes or any valid rule, order, or regulation promulgated thereunder, shall be denied access to commerce; and providing for stringent penalties for the waste of either oil or gas.

### "Article V

"It is not the purpose of this compact to authorize the States joining herein to limit the production of oil or gas for the purpose of stabilizing or fixing the price thereof, or create or perpetuate monopoly, or to promote regimentation, but is limited to the purpose of conserving oil and gas and preventing the avoidable waste thereof within reasonable limitations.

### "Article VI

"Each State joining herein shall appoint one representative to a commission hereby constituted and designated as The Interstate Oil Compact Commission, the duty of which said commission shall be to make inquiry and ascertain from time to time such methods, practices, circumstances, and conditions as may be disclosed for bringing about conservation and the prevention of physical waste of oil and gas, and at such intervals as said commission deems beneficial it shall report its findings and recommendations to the several States for adoption or rejection.

"The Commission shall have power to recommend the coordination of the exercise of the police powers of the several states within their several jurisdictions to promote the maximum ultimate recovery from the petroleum reserves of said states, and to recommend measures for the maximum ultimate recovery of oil and gas. Said Commission shall organize and adopt suitable rules and regulations for the conduct of its business.

"No action shall be taken by the Commission except: (1) by the affirmative votes of the majority of the whole number of the compacting States, represented at any meeting and (2) by a concurring vote of a majority in interest of the compacting States at said meeting, such interest to be determined as follows: such vote of each State shall be in the decimal proportion fixed by the ratio of its daily average production during the preceding calendar half-year to the daily average production of the compacting States during said period.

### "Article VII

"No State by joining herein shall become financially obligated to any other State, nor shall the breach of the terms hereof by any State subject such State to financial responsibility to the other States joining herein.

### "Article VIII

"This compact shall expire September 1, 1937. But any State joining herein may, upon sixty (60) days notice, withdraw herefrom.

"The representatives of the signatory States have signed this agreement in a single original which shall be deposited in the archives of the Department of State of the United States, and a duly certified copy shall be forwarded to the Governor of each of the signatory States.

"This compact shall become effective when ratified and approved as provided in Article I. Any oil-producing State may become a party hereto by affixing its signature to a counterpart to be similarly deposited, certified, and ratified.

"Done in the City of Dallas, Texas, this sixteenth day of February, 1935.

"And whereas, it is desired to extend and renew said Compact for the period of two (2) years from September 1, 1937, its expiration date;

"Now, therefore, this writing witnesseth:

"It is hereby agreed that the said Compact entitled 'An interstate compact to conserve oil and gas' executed in the City of Dallas, Texas, on the 16th day of February, 1935, and now on deposit with the Department of State of the United States, a correct copy of which appears above, be, and the same is hereby, extended for a period of two (2) years from September 1, 1937, its date of expiration, this agreement to become effective within those States joining herein when executed by any three of the States of Texas, Oklahoma, California, Kansas, and New Mexico, and consent thereto is given by Congress.

"The signatory States execute this agreement in a single original which shall be deposited in the archives of the Department of State of the United States and a duly certified copy thereof shall be forwarded to the Governor of each of the signatory States.

"Executed as of this the 10th day of May, 1937, by the several undersigned States, at their several Capitols, through their proper officials thereunto duly authorized by resolutions or statutes of the several States."

SEC. 2. The right to alter, amend, or repeal the provisions of section 1 is hereby expressly reserved.

Approved, August 10, 1937.

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[H. Rept. No. 1360, 75th Cong., 1st sess.]

The Committee on Interstate and Foreign Commerce, to whom was referred the joint resolution (H. J. Res. 456) consenting to an interstate oil compact to conserve oil and gas, having considered the same, report thereon with a recommendation that it pass.

House Joint Resolution 456, introduced by the gentleman from Oklahoma, Mr. Boren, is identical with House Joint Resolution 460, which I introduced and the interstate compact set forth in the resolution reported herewith is identical with that contained in House Joint Resolution 407, approved August 27, 1935, in Public Resolution No. 64 of the Seventy-fourth Congress, which I also introduced.

From letter dated July 8, 1937, from Hon. Harold L. Ickes, Secretary of the Interior to the Honorable Secretary of State, Mr. Cordell Hull (which letter is a part of H. Doc. 307, the message from the President of the United States recommending the passage of this legislation) is the following paragraph:

"The interstate compact to conserve oil and gas was executed in Dallas, Tex., on February 16, 1935, and ratified subsequently by the legislatures of the States of New Mexico, Kansas, Oklahoma, Illinois, Colorado, and Texas. The formation of such a compact was encouraged by the Interstate and Foreign Commerce Subcommittee of the House of Representatives which investigated the petroleum industry in 1934 and prepared the bill, H. R. 9053, which was reported favorably by the Interstate and Foreign Commerce Committee in August 1935. In addition to providing for the approval of the compact, the bill, H. R. 9053, contained other provisions which were regarded by the committee as essential to the declaration of a permanent policy of the Government dealing with the petroleum industry. Only that portion of the bill which consented to the compact was enacted by the Seventy-fourth Congress in Public Resolution No. 64, approved August 27, 1935."

It is correct, as Secretary Ickes stated that the subcommittee of the Interstate and Foreign Commerce Committee of the House, over which subcommittee I presided as chairman in 1934, investigating under a House resolution the petroleum industry, gave considerable encouragement to the oil-producing States to the formation of an interstate compact rather than have their problems regimented in Washington as was being attempted at that time. While our efforts were not by any means controlling in bringing the States together in the final execution of the compact in Dallas, Tex., on February 16, 1935, the members of our committee felt that the prominence given in our hearings to the possibility of a compact and the benefits to be derived thereon, furnished the necessary encouragement to the States affected.

It is further true that H. R. 9053 was reported during the Seventy-fourth Congress upon the recommendation of our subcommittee, which bill provided for the approval of the compact and contained other provisions regarded by us as advisable permanent national policy at that time. It is the belief of the writer of this report that other provisions of that bill will eventually become law.

I am frank to say that with the efficiency of the Bureau of Mines and the Petroleum Administrative Board, both under the Department of the Interior, dealing primarily for the past 2 years with shipments of oil in interstate commerce in violation of State law, there is not the same need for a separate agency as I advocated in the past, to administer the provisions of such an act as was contemplated in H. R. 9053.

There is no occasion for a long report on this resolution, because the report of the Seventy-fourth Congress is available and the letter from the President of the United States, the State Department, and the Interior Department, as embodied in House Document 306 of the Seventy-fifth Congress, endorsing the renewal of the compact, presents at considerable length reasons therefor.

Article 1, section 10, of the Constitution of the United States provides in part as follows:

"No State shall, without the consent of Congress, lay any duty on tonnage, keep troops or ships of war in time of peace, enter into any agreement or compact with another State, or with a foreign power * * *."

The aforegoing constitutional provision contemplated just such concerted action on the part of the States as we find embodied in the compact set forth in this resolution.

Nothing we can think of is more important at the present time than the conservation of our oil resources. All States possessing these great resources should be and, I believe, are anxious to do so and the great consuming portion of the country is equally concerned. Oil is not unlimited, as many do not realize, and the time when substitutes or greater improvements of recovery or refining process will be of major importance is not so very far distant.

A single State, however, is not willing to impose upon its people legal restrictions in the recovery of this resource from their land—which recovery can be restricted, as the courts have well defined, provided such statutes are for the purpose of preventing waste thereof—unless neighboring and other oil-producing States are willing to do likewise. The Federal Government has too great an interest not only in its own activities but in those of the consuming States and the problems of industry and individuals, not to lend encouragement to the efforts on the part of the great producing States of the country to solve their problems through concerted action of this character.

We are asked in this resolution to give consent to such a request, which is in the form of a compact dated February 16, 1935, expiring September 1, 1937, unless it is extended for a 2-year period to September 1, 1939, as requested by the States set forth therein.

It should be said that all that is capable of being accomplished under the compact of 1935, which we now recommend be extended, has not been accomplished, in fact not so much as we had hoped for, but the interstate commission provided for therein does supply the means for frequent contact on this all-important subject between the States most concerned therewith. It is our hope that at the end of this new period, that is, by September 1, 1939, that more uniformity in State statutes will be found and more accomplishments will be reported by the several groups functioning under the compact commission set-up.

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[PUBLIC RESOLUTION—NO. 31—76TH CONGRESS]

[CHAPTER 337—1ST SESSION]

[H. J. Res. 329]

JOINT RESOLUTION Consenting to an interstate oil compact to conserve oil and gas

*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That the consent of Congress is hereby given to an extension and renewal for a period of two years from September 1, 1939, of the interstate compact to conserve oil and gas, executed in the city of Dallas, Texas, the 16th day of February 1935 by the representatives of the States of Oklahoma, Texas, California, and New Mexico, and thereafter recommended for ratification by the representatives of the States of Arkansas, Colorado, Illinois, Kansas, and Michigan, and subsequently ratified by the States of New Mexico, Kansas, Oklahoma, Illinois, Colorado, and Texas, which said compact was deposited in the Department of State of the United States, and thereafter such compact was, by the President, presented to the Congress and the Congress gave consent to such compact by H. J. Res. 407, approved August 27, 1935 (Public Resolution Numbered 64, Seventy-fourth Congress), and which said compact was thereafter extended and renewed for a period of two years from September 1, 1937, by an agreement executed in New Orleans, Louisiana, the 10th day of May 1937, by the representatives of the States of Oklahoma, Texas, Kansas, and New Mexico, and was duly ratified by the States of Oklahoma, Texas, Kansas, New Mexico, Illinois, and Colorado, and was deposited in the Department of State of the United States, and thereafter such extended and renewed compact was, by the President, presented to the Congress and the Congress gave consent to such extended and renewed compact by S. J. Res. 183, approved August 10, 1937 (Public Resolution Numbered 57, Seventy-fifth Congress).

The extended and renewed compact, dated the 5th day of April 1939, duly executed by the representatives of the States of Oklahoma, Texas, Kansas, New Mexico, Colorado, and Michigan, and duly authorized and ratified by the said States of Oklahoma, Texas, Kansas, New Mexico, Colorado, and Michigan, and which extended and renewed compact has been deposited in the Department of State of the United States, reads as follows:

"AN AGREEMENT TO EXTEND THE INTERSTATE COMPACT TO CONSERVE OIL AND GAS

"Whereas, on the 16th day of February 1935, in the city of Dallas, Texas, there was executed 'An interstate compact to conserve oil and gas' which was thereafter formally ratified and approved by the States of Oklahoma, Texas, New Mexico, Illinois, Colorado, and Kansas, the original of which is now on deposit with the Department of State of the United States, a true copy of which follows:

"AN INTERSTATE COMPACT TO CONSERVE OIL AND GAS

"ARTICLE I

"This agreement may become effective within any compacting State at any time as prescribed by that State, and shall become effective within those States ratifying it whenever any three of the States of Texas, Oklahoma, California, Kansas, and New Mexico have ratified and Congress has given its consent. Any oil-producing State may become a party hereto as hereinafter provided.

"ARTICLE II

"The purpose of this compact is to conserve oil and gas by the prevention of physical waste thereof from any cause.

"ARTICLE III

"Each State bound hereby agrees that within a reasonable time it will enact laws, or if laws have been enacted, then it agrees to continue the same in force, to accomplish within reasonable limits the prevention of:

"(a) The operation of any oil well with an inefficient gas-oil ratio.

"(b) The drowning with water of any stratum capable of producing oil or gas, or both oil and gas in paying quantities.

"(c) The avoidable escape into the open air or the wasteful burning of gas from a natural-gas well.

"(d) The creation of unnecessary fire hazards.

"(e) The drilling, equipping, locating, spacing, or operating of a well or wells so as to bring about physical waste of oil or gas or loss in the ultimate recovery thereof.

"(f) The inefficient, excessive, or improper use of the reservoir energy in producing any well.

"The enumeration of the foregoing subjects shall not limit the scope of the authority of any State.

"ARTICLE IV

"Each State bound hereby agrees that it will, within a reasonable time, enact statutes, or if such statutes have been enacted, then that it will continue the same in force, providing in effect that oil produced in violation of its valid oil and/or gas-conservation statutes or any valid rule, order, or regulation promulgated thereunder, shall be denied access to commerce; and providing for stringent penalties for the waste of either oil or gas.

"ARTICLE V

"It is not the purpose of this compact to authorize the States joining herein to limit the production of oil or gas for the purpose of stabilizing or fixing the price thereof, or create or perpetuate monopoly, or to promote regimentation, but is limited to the purpose of conserving oil and gas and preventing the avoidable waste thereof within reasonable limitations.

"ARTICLE VI

"Each State joining herein shall appoint one representative to a commission hereby constituted and designated as 'The Interstate Oil Compact Commission,' the duty of which said Commission shall be to make inquiry and ascertain from time to time such methods, practices, circumstances, and conditions as may be disclosed for bringing about conservation and the prevention of physical waste of oil and gas, and at such intervals as said Commission deems beneficial it shall report its findings and recommendations to the several States for adoption or rejection.

"The Commission shall have power to recommend the coordination of the exercise of the police powers of the several States within their several jurisdictions to promote the maximum ultimate recovery from the petroleum reserves of said States, and to recommend measures for the maximum ultimate recovery of oil and gas. Said Commission shall organize and adopt suitable rules and regulations for the conduct of its business.

"No action shall be taken by the Commission except: (1) By the affirmative votes of the majority of the whole number of the compacting States, represented at any meeting, and (2) by a concurring vote of a majority in interest of the compacting States at said meeting, such interest to be determined as follows: Such vote of each State shall be in the decimal proportion fixed by the ratio of its daily average production during the preceding calendar half-year to the daily average production of the compacting States during said period.

### "ARTICLE VII

"No State by joining herein shall become financially obligated to any other State, nor shall the breach of the terms hereof by any State subject such State to financial responsibility to the other States joining herein.

### "ARTICLE VIII

"This compact shall expire September 1, 1937. But any State joining herein may, upon sixty days' notice, withdraw herefrom.

"The representatives of the signatory States have signed this agreement in a single original which shall be deposited in the archives of the Department of State of the United States, and a duly certified copy shall be forwarded to the governor of each of the signatory States.

"This compact shall become effective when ratified and approved as provided in article 1. Any oil-producing State may become a party hereto by affixing its signature to a counterpart to be similarly deposited, certified, and ratified.

"Done in the city of Dallas, Texas, this 16th day of February 1935."

Whereas said Interstate Compact was heretofore duly renewed and extended for two years from September 1, 1937, its original expiration date, to September 1, 1939; and

Whereas it is desired to again extend and renew said Interstate Compact to Conserve Oil and Gas for another period of two years from September 1, 1939, its present expiration date, to September 1, 1941:

Now, therefore, this writing witnesseth:

It is hereby agreed that the said Compact entitled "An Interstate Compact to Conserve Oil and Gas" executed in the city of Dallas, Texas, on the 16th day of February 1935, and now on deposit with the Department of State of the United States, a correct copy of which appears above, be, and the same hereby is, extended for a period of two years from September 1, 1939, its present date of expiration, this agreement to become effective within those States joining herein when executed by any three of the States of Texas, Oklahoma, California, Kansas, and New Mexico, and consent thereto is given by Congress.

The signatory States executed this agreement in a single original which shall be deposited in the archives of the Department of State of the United States and a duly certified copy thereof shall be forwarded to the governor of each of the signatory States.

Executed as of this the 5th day of April 1939 by the several undersigned States at their several capitols, through their proper officials thereunto duly authorized by statutes, resolutions, or proclamations of the several States.

SEC. 2. The right to alter, amend, or repeal the provisions of section 1 is hereby expressly reserved.

Approved, July 20, 1939.

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[H. Rept. No. 1017, 76th Cong., 1st sess.]

The Committee on Interstate and Foreign Commerce, to whom were referred the joint resolutions (H. J. Res. 329 and H. J. Res. 330, identical resolutions, introduced on the same day by Congressman Boren and Congressman Lea, respectively), consenting to an interstate oil compact to conserve oil and gas, having considered the same, report thereon with the recommendation that House Joint Resolution 329 pass.

This is a renewal of the original oil compact which was approved by Congress on August 27, 1935, and which was extended for an additional 2 years on August 10, 1937, the latter extension expiring on September 1, 1939.

To the compact of 1935, New Mexico, Kansas, Oklahoma, Illinois, Colorado, and Texas were signatory States, and the same States in 1937 requested a renewal of the compact in practically identical language. At this time the compact before us is from the same States, with the exception of Illinois and the addition of the State of Michigan, so that this resolution ratifies the request of the States of New Mexico, Kansas, Oklahoma, Colorado, Texas, and Michigan.

In 1934, following an investigation of the petroleum industry which your committee conducted in response to a House resolution, the committee filed a report and subsequently, on July 14, 1935, filed an additional report, accompanying H. R. 9053, in which is found the following statement:

"As the initial report of the subcommittee will disclose, they gave, during the investigation, considerable encouragement to the formation of the interstate compact and are glad to state in this report that which is known to many Members of the House, that through the efforts of many progressive Governors of a number of the oil-producing States, and we feel to some extent as a result of the encouragement of the subcommittee, such a compact has been entered into."

In Report No. 1360, of the Seventy-fifth Congress, your committee, in recommending consent of Congress to a renewal of the oil compact, stated:

"A single State, however, is not willing to impose upon its people legal restrictions in the recovery of this resource from their land—which recovery can be restricted, as the courts have well defined, provided such statutes are for the purpose of preventing waste thereof—unless neighboring and other oil-producing States are willing to do likewise. The Federal Government has too great an interest, not only in its own activities but in those of the consuming States and the problems of industry and individuals, not to lend encouragement to the efforts on the part of the great producing States of the country to solve their problems through concerted action of this character."

The President of the United States has, and your committee feels very properly, recommended the enactment of necessary legislation giving consent to the agreement of April 5, 1939, presented to the Congress by the States hereinbefore named, for that purpose. The Presidential message reads as follows:

*To the Congress of the United States:*

I transmit herewith a report of the Secretary of State enclosing a certified copy of An Agreement to Extend the Interstate Compact to Conserve Oil and Gas, executed as of April 5, 1939, by the Governors of the States of Oklahoma, New Mexico, Kansas, Colorado, Texas, and Michigan, which has been deposited in the archives of the Department of State in accordance with the provision contained therein. The agreement refers to the interstate compact to conserve oil and gas executed at Dallas, Tex., on February 16, 1935, which received the consent of the Congress in Public Resolution No. 64, Seventy-fourth Congress, approved August 27, 1935 (49 Stat. 939). As that compact would have expired on September 1, 1937, an agreement extending its provisions for 2 years was executed as of May 10, 1937, by the Governors of the States of Oklahoma, Texas, Kansas, New Mexico, and Colorado, and received the consent of Congress in Public Resolution No. 57, Seventy-fifth Congress, approved August 10, 1937 (50 Stat. 617). As the above-mentioned compact, in accordance with the extension agreement of May 10, 1937, will expire on September 1, 1939, the present agreement provides that the original compact shall continue in force for 2 years from that date. In a letter from the Acting Secretary of the Interior dated June 8, 1939, enclosed with the report of the Secretary of State, the opinion is expressed that suitable legislation should be enacted by the Congress giving its consent to the extension to September 1, 1941, of the interstate compact to conserve oil and gas.

Accordingly I hope that Congress will enact legislation giving its consent to the agreement executed as of April 5, 1939, as required by article I, section 10, of the Constitution of the United States.

FRANKLIN D. ROOSEVELT.

THE WHITE HOUSE, *June 15, 1939.*

In view of the foregoing, and especially the fact that an act similar to that recommended herewith has been passed on two previous occasions, we find no occasion for a lengthy report to accompany this resolution.

Article 1, section 10, of the Constitution of the United States provides in part as follows:

"No State shall, without the consent of Congress, lay any duty on tonnage, keep troops or ships of war in time of peace, enter into any agreement or compact, with another State, or with a foreign power * * *."

The foregoing constitutional provision contemplates just such concerted action on the part of the States as we find embodied in the compact set forth in this resolution.

We recommend the enactment of this resolution, which extends the interstate compact to conserve oil and gas from September 1, 1939, to September 1, 1941.

Mr. Cole. In response to the President's request that the investigation of 1934 be brought up to date and that H. R. 7372 be definitely considered by the committee, the committee requested of the Interior Department aid and assistance similar to that we had in 1934, which work resulted in a large part of volume 1 and practically all of volume 2 of the hearing which are referred to quite often as the technical part of the work.

We have been quite fortunate in receiving from the Interior Department the assistance of highly capable personnel in the various agencies in the Interior Department dealing with petroleum. These gentlemen are here to present their work with such comments as they care to make. Preliminary to the report of the staff to which I have referred, the first witness will be Mr. David Hudson, assistant solicitor of the Department of the Interior.

Mr. Hudson has been asked to present a summary of the bill H. R. 7372, and explain the provisions thereof, as he assisted in the drafting of the bill. Mr. Hudson.

## STATEMENT OF DAVID HUDSON, ASSISTANT SOLICITOR, DEPARTMENT OF THE INTERIOR

Mr. Hudson. Mr. Chairman, I have a statement——

Mr. Cole. Mr. Hudson, at this point I think I should announce it is the purpose of the committee to conclude this week what might be termed the Government's side of this problem, that is, the techincal work, with Mr. Hudson's testimony and statement by Secretary of the Interior Ickes. The committee will then adjourn until possibly in December, but before the next session of Congress, for the purpose of hearing the State regulatory commission or other representative of oil-producing States. Where that hearing will be held has not yet been determined, but the response of the State agencies to the requests of the committee suggests very definitely such a hearing will take place. I think it is safe to say the aforegoing will be about all the testimony to be taken between now and January. Should we determine later to take some testimony at the same time we hear from the State commissions, public announcement will be made.

I just make that announcement for the benefit of all interested parties.

All right, Mr. Hudson.

Mr. Hudson. Mr. Chairman, I have a statement written out which is a summary of the provisions of H. R. 7372 and gives a brief analysis of those provisions and of the functions authorized by the bill and the manner in which they are authorized to be exercised. I have copies of the statement for the use of the committee. First are indicated the general administrative provisions of the bill.

### TITLE

Section 1 provides that the act may be cited as the "Petroleum Conservation Act of 1939."

### FINDINGS

Section 2 (a) contains the findings of the Congress concerning the effect on the national defense and on interstate commerce of the employment of methods and practices, in the production of petroleum in the United States, which are wasteful of petroleum and of reservoir energy available for the production thereof.

### POLICY

In section 2 (b) it is declared to be the policy of Congress to "further the conservation of petroleum" by eliminating such wasteful methods and practices insofar as they may be avoidable, and to "encourage and assist the various States in their efforts to prevent the waste of petroleum."

### DEFINITIONS

Section 3 (a) contains definitions of certain terms used in the bill and section 3 (b) authorizes the Commissioner to define other technical terms.

### AGENCY

Section 4 of the bill establishes the Office of Petroleum Conservation as the agency to administer the law. The office is placed in the Department of the Interior and under the direction of a Commissioner to be appointed by the President. All other personnel of the office, whether appointed or transferred, are to be subject to the civil-service laws and the Classification Act of 1923.

### SUBSTANTIVE PROVISIONS

#### I. INVESTIGATION

The Commissioner is authorized in section 5 (a) of the bill to investigate and determine, as to any field in the United States, whether the production of oil and gas therein involves avoidable physical waste of crude oil or avoidable waste of reservoir energy available for the recovery of crude oil. The investigation and determination are to be carried out under a definite formula laid down by the Congress. Section 5 (c) enumerates the several characteristics of petroleum deposits and conditions of production therefrom which the Commissioner is directed to consider in such an investigation; and the determination as to whether or not waste occurs is to be made by applying, to the facts brought out by the investigation, the precise definitions of waste set out in section 5 (b). The Congress will thus have determined what constitutes physical waste of crude oil and waste of reservoir energy, and the administrative inquiry will establish the facts which, in the particular field, do or do not come within that determination of Congress.

Hearings held in the course of any investigation authorized in section 5 (a) are required by section 16 to be held in the Federal judicial district in which the field under investigation, or any part thereof, is situated. The proceedings for ascertainment of the facts will, therefore, be readily accessible to operators, State officials, and other parties interested in and having knowledge of the situation which obtains in the field under inquiry.

The first duty of the Commissioner upon completion of the investigation of any field, whether waste is or is not found to exist, is to make known the findings of fact "to the State agency charged with the regulation of petroleum development and production, or to the Governor where there is no such agency, of the State or States in which such field is situated," and to give to the findings such other publicity as he shall deem advisable (sec. 6).

The Commissioner is authorized to conduct investigations and hearings jointly with any duly authorized State official or agency and with agencies acting under agreements between States. This will permit participation by State officials in the administrative inquiries to establish facts. The authorization does not extend to the participation of Federal officials in the conduct of State proceedings.

The necessary powers granted relating to the conduct of investigations and hearings are those prescribed in the Securities Exchange Act of 1934, pertinent provisions of which are incorporated by reference in section 16 of the bill.

### II. RESEARCH

Section 10 (a) authorizes the Commissioner to conduct experimentation, investigation, and demonstration relating to the technical phases of production, refining, storage, transmission, and distribution of petroleum and its products; to investigate reserves of crude oil, including comparative studies of foreign and domestic reserves; and to publish pertinent findings and data. The functions here prescribed are those of a service agency. Duplication or conflict is avoided by provision for the transfer to the Office of similar functions exercised elsewhere.

### III. COOPERATION

The Commissioner is authorized in section 11 to cooperate with State officials and agencies, with agencies acting under joint agreements between two or more States, and with educational and research institutions.

In addition to the provisions of the bill elsewhere noted, providing for cooperation with State and other agencies in the administration of the bill, section 18 establishes a Council on Petroleum Conservation as an agency designed to promote the fullest cooperation and exchange and coordination of problems and information pertinent to petroleum conservation. The council is to consist of 18 members appointed by the Secretary, 9 of whom are State officials engaged in the administration of petroleum conservation laws, 6 of whom are engaged in the production of petroleum, and 3 of whom are engaged in teaching subjects related to petroleum at educational institutions. The council is charged with the duty of maintaining an interchange of information between its members and the Office as to "production methods and practices which will tend to effect the conservation of petroleum." The bill provides that the body shall meet annually with representatives of the Federal Government to confer on matters "concerning the prevention of waste in petroleum production and the civilian and military petroleum needs of the Nation."

### IV. ELIMINATION OF WASTE

If, upon investigation of any field, the Commissioner finds that waste is not occurring, he is to take no further action after the publication of such finding. If it is found that avoidable waste is occurring or is imminent under the methods and practices employed in the field, such waste is to be eliminated and prevented by either (1) voluntary agreement among the operators in the field or (2) enforcible regulations issued by the Commissioner.

For the first alternative the Commissioner is authorized in section 7, upon the issuance of findings of fact, to consider any proposed voluntary agreement among the operators designed to eliminate the avoidable waste found. If a proposed agreement is such as to be effective in eliminating waste, the Commissioner is directed to approve such agreement, and no further action is to be taken as to the waste which is controlled by the agreement so long as the agreement continues to be effective for its purpose.

Where necessary, the second alternative is to be employed as directed in section 6 (b). The Commissioner is there directed to promulgate regulations which will "designate and define with particularity those methods and practices which he shall find to be wasteful." The bill provides that the Commissioner shall consider and make proper provision concerning the several factors of waste there enumerated by the Congress. The enumeration of those factors of waste by Congress, together with the definitions of waste set out in section 5 (b), so informs persons affected by the bill as to enable them, in many instances, to evaluate the conditions of operation with which they are concerned and to take such corrective measures as will make unnecessary the promulgation of regulations authorized in the bill.

In section 6 (c) are enumerated three situations which, in the investigation of a field, the Commissioner is directed to consider as prima facie evidence of avoidable waste. As prima facie evidence, it is rebuttable by the production of facts establishing that avoidable waste as defined in the bill does not attend the situations set out. The first prima facie case consists in the operation of any flowing well producing either crude oil or gas at substantially its open-flow capacity. The second case is the production of crdue oil from any flowing well at a rate which in relation to the known reserves is substantially in excess of the production rate in relation to known reserves in other fields where the Commissioner has already found operations to be nonwasteful. These two situations are in the nature of emergency provisions which will permit the Commissioner to promulgate suitable regulations to avoid irreparable waste occurring at a relatively rapid rate pending a definite determination of the effect of such production. Final regulations are to be based on the results of the investigation upon its completion, as in the case of any other field.

Mr. Cole. Let me interrupt you at that point, Mr. Hudson. I am asked in a letter by the Phillips Petroleum Co. this question pertaining to section 6 (c) (2): Assuming that every well is producing at a nonwasteful rate, that the relation between such rate and the reserves of the well or the reserves of the deposit must necessarily be different as to every well and could not conceivably be the same in any two deposits; in speculating upon the reason for the provision it occurred to me that as a matter of so-called "equitable allocation" it may have been an effort to suggest that each well in the United States should always produce at a rate which bore the same relationship to its reserves or the reserves of the deposit. If there is some justification for this that they have overlooked, they would like to know it.

Now, if you are not equipped to answer that question now, I hope that some of the others to follow will do so.

Mr. HUDSON. I might just say this, Mr. Chairman: That section 6 (c) (2) does not contemplate that the same relationship between the production and reserves is to be established as a continuing requirement. As I have indicated, paragraph 2 is in the nature of an emergency provision which would permit the Commissioner, upon finding a field where the production rate in relation to the reserves was as you have stated, substantially in excess of the same relationship in other fields as to which investigation had been made under the bill, to promulgate such suitable regulation as may be necessary until the actual facts are determined with relation to the definition of waste in the bill; and at that time this ceases to be a standard and the definition laid down by the Congress is the standard for the final regulation.

Mr. PEARSON. May I ask a question before you leave that page, Mr. Hudson? Dealing with this question of waste, you provide for two alternatives, one a voluntary agreement among the operators or enforceable regulations issued by the Commissioner.

Mr. HUDSON. Yes, sir.

Mr. PEARSON. Now, in the next paragraph you state this [reading]:

> If a proposed agreement is such as to be effective in eliminating waste, the Commissioner is directed to approve such agreement, and no further action is to be taken as to the waste which is controlled by the agreement so long as the agreement continues to be effective.

Now, under that language you vest absolutely in the Commissioner the right to determine the effectiveness of any voluntary agreement which the operators themselves might make, do you not?

Mr. HUDSON. Yes, sir; I think in the same manner that the Commissioner determines whether the facts that he ascertains from his investigation constitute waste or not under the bill, in the same manner he will determine whether the provisions of an agreement which prescribe or limit certain methods of operation would likewise come within the definition.

Mr. PEARSON. Now, do you anywhere in this bill provide for an appeal or any other recourse which the operator might take from an abuse of the discretionary rights which is here vested in the Commissioner?

Mr. HUDSON. Yes; in the event that approval is not given to the agreement and regulations are issued.

Mr. PEARSON. Yes. I am just assuming a man in that position might abuse that discretionary right or administer it improperly.

Mr. HUDSON. Yes, sir.

Mr. PEARSON. And the operators might insist that the agreement which they had entered into was effective. Now, what I have in mind is that such a situation might result in a stalemate unless some provision is made for recourse from a situation of that kind.

Mr. Hudson. No direct recourse is provided after that decision.

Mr. Pearson. That is final?

Mr. Hudson. The recourse of the operator is with respect to the regulations then issued.

Mr. Pearson. Just as a matter of suggestion, would you consider that the final approval of such an agreement might be referred to this Council?

Mr. Hudson. The Council has no other administrative or quasi-judicial function as it is set up in the bill.

Mr. Pearson. It is just advisory?

Mr. Hudson. Yes, sir.

Mr. Pearson. I am just suggesting that as you go along there.

Mr. Hudson. The third prima facie case of waste is the failure, subsequent to 1 year after the effective date of the act, of the producers in a field to determine with reasonable accuracy the factors of waste listed in section 5 (c) as applied to the field. This case is set up in lieu of an express provision directing the continued and reasonably accurate determination of the factors which the Congress has enumerated as factors of waste. Its justification as a prima facie case lies in the fact that without a determination, such as is required, it cannot be known whether or not waste exists, and the strong probability is that it is present.

Section 9 declares it to be unlawful, during the effective period of any applicable regulation, to employ any method or practice designated and defined therein as wasteful.

Section 17 (b) specifically provides that the power to promulgate regulations shall include the power to alter, amend, modify, suspend the operation of, and rescind such regulations. Thus, for example, after the issuance of findings of fact as to the conditions in a field, the furnishing of those findings to the State officials, and the preparation of regulations designating and defining the wasteful methods and practices, the Commissioner may defer the effective date of the regulations for such period as he may deem advisable to permit the correction of conditions by State or voluntary action.

### V. ENFORCEMENT

As previously noted, section 9 prohibits the employment of methods or practices designated and defined as waseful by regulation. Section 19 of the bill extends the operation of the Connally law (February 22, 1935, 49 Stat. 30), as amended, so as to prohibit the shipment or transportation in interstate commerce not only of crude oil and the products thereof produced in excess of quantities permitted by State law but also of that produced in violation of any State law or regulation or by methods or practices which are unlawful under this bill and the regulations issued thereunder.

The Federal district courts, including the District Court for the District of Columbia, are given exclusive jurisdiction of violations of the act or regulations, and of all actions or suits for enforcement of the act and regulations. Judgments and decrees of those courts are subject to review as provided in the Judicial Code (sec. 14).

When it shall appear to the Commissioner that any person is violating the act or regulations thereunder, he may apply to any district court for an appropriate injunction, restraining order, or writ of mandamus (sec. 13) ; or if it shall appear to be advisable in the circumstances, either for purposes of expedition or by reason of the nature of the supposed violation or the facts constituting it, or otherwise, first, to obtain a construction of the regulation in question in a quasi-judicial proceeding, the Commissioner is authorized in section 15 to serve a written complaint containing notice of a hearing to be held before the Commissioner (or his designated agent or agency). After such a hearing held under the requirements and within the limitations of section 15, the Commissioner is directed to make his finding and issue such order as may be warranted requiring elimination of the waste involved in the violation, if any. After the issuance of such an order the Commissioner may petition any United States circuit court of appeals, including the Court of Appeals of the District of Columbia, for enforcement of such order, and any party to the proceedings before the Commissioner who is affected by the order may obtain a review thereof by the appropriate circuit court of appeals. Neither of the latter proceedings shall, unless so ordered by the court, operate as a stay of the Commissioner's order (sec. 15).

### VI. PENALTIES

Section 12 provides the penalties for violation of the act or regulations promulgated thereunder, for failure to comply with an order of the Commissioner, for willfully interfering with persons engaged in the performance of duties pursuant to the act, and for willfully and knowingly making false statements as to any material fact in any report or document required by the act or regulations.

### VII. CONSOLIDATION

The bill also provides for the consolidation in a single agency of those functions, now exercised by Federal agencies, which fall within the scope of the legislation. Section 8, which makes the provisions of the bill applicable to all deposits owned by the United States, transfers existing functions of the Office, directs the Secretary to transfer to the Office similar functions exercised elsewhere in the Department of the Interior, and authorizes the President, in his discretion, to transfer similar functions exercised elsewhere in the Government.

Section 10 (b) provides that the Office shall exercise such functions now vested in the Secretary of the Interior relating to cooperative or unit plans of development or operation as the Secretary shall designate.

Section 10 (c) transfers to the Office the functions of the Petroleum Conservation Division.

Section 10 (d) transfers to the Office all functions vested in the President by the Connally law except those under section 4 of that act which relate to the suspension of the operation of the act.

Mr. Cole. Mr. Hudson, who assisted in the preparation of the bill?

Mr. Hudson. In the preparation of the bill, sir?

Mr. Cole. Yes.

Mr. Hudson. It was prepared in conference with the technical people of the agencies of the Department, and the work was reviewed.

Mr. Cole. By that you mean whom?

Mr. Hudson. Sir?

Mr. Cole. By that you mean which technical agencies?

Mr. Hudson. In the Petroleum Conservation Division, the Bureau of Mines, the Geological Survey, and, I think, representatives of the Office of Indian Affairs in conference.

Mr. Cole. Mr. Wolverton?

Mr. Wolverton. Mr. Hudson, I was a little late in arriving, and you may have given the background of your connection with the Government, which I did not hear. With what department are you connected?

Mr. Hudson. In the Department of the Interior, sir; Assistant Solicitor.

Mr. Wolverton. Who is your immediate superior?

Mr. Hudson. Solicitor Margold.

Mr. Wolverton. Did Mr. Margold assist in the drawing of this legislation?

Mr. Hudson. He reviewed the work done on it.

Mr. Wolverton. What is the difference as to the purpose of this bill, known as H. R. 7372, and the so-called Margold bill that this committee had brought to its attention in our hearings some 4 or 5 years ago?

Mr. Hudson. I am not familiar with the provisions of that bill, sir.

Mr. Wolverton. How long have you been connected with the Department?

Mr. Hudson. Since February 1937.

Mr. Wolverton. And in the preparation of this bill you have had no knowledge of the so-called Margold bill?

Mr. Hudson. No, sir; I did not consider that bill.

Mr. Wolverton. You do not feel, then, in a position to give this committee any information with respect to whether this bill will accomplish the same purpose as was sought to be accomplished by the Margold bill?

Mr. Hudson. No, sir; I don't know enough about that bill to say.

Mr. Wolverton. Does this bill directly or indirectly seek to control marketing?

Mr. Hudson. No, sir; it does not.

Mr. Wolverton. I have noticed in my reading on the subject a reference that had been made to the bill by the trade magazine known as the National Petroleum News. In the issue of October 25, 1939, it would seem as if the opinion is held by some, at least, that the effect of this bill would be not only to control production but also the flow of products from the refineries, perhaps even to the terminals, and perhaps to the consumer; and that not only the price would be affected but the amount of the national defense supplies of crude and even the dealers' supply of products would be controlled.

Do you think there is any justification for that opinion?

Mr. Hudson. I think that description, in that language, goes far beyond the provisions or effect of this bill, sir.

Mr. Wolverton. It is further stated as an expression of opinion upon the part of this writer that the frank and outspoken aim of the

Roosevelt administration is to have it given power over the oil industry which, according to the proposed bill, seems to be as great as it attempted to get over coal.

Is that the purpose of this bill?

Mr. Hudson. It does not parallel, as I understand it, the legislation relative to coal. It is limited to the physical aspects of waste in production.

Mr. Wolverton. Are you familiar with the criticisms that have been raised with respect to the broad scope of this legislation?

Mr. Hudson. I had seen similar statements relative to the bill in that vein.

Mr. Wolverton. Well, just how far is it the intention to go with this bill? Am I to understand that it is limited to production?

Mr. Hudson. That is correct, sir.

Mr. Wolverton. Who will be the final determining authority as to what is or is not waste?

Mr. Hudson. Under the standards laid down in the definition of waste in the bill, it is the duty of the Commissioner to apply the facts found by the investigation in the fields to that definition, and to arrive then at the determination as to whether those facts constitute, under that definition, what has been determined in the bill to constitute waste.

Mr. Wolverton. Well, at the present time the Federal Government exercises some assistance to the State regulatory bodies in determining what is a proper production ratio; but under this bill would it be possible for a State regulatory body to have a different opinion as to the amount of production that would be proper than that which was expressed by this Federal agency?

Mr. Hudson. Yes, sir; I think that would be possible, and I think that recognition of that is one of the reasons for the cooperative provisions which appear in the bill, particularly in connection with the investigation in the field and the authority to have participation by State officials.

Mr. Wolverton. I am endeavoring to ascertain as to whether the Federal agency which is provided for by this bill would have the right, not only to disagree with production figures fixed by a State regulatory body, but also whether in the event of a disagreement it would have the power to set aside the State finding and set up its own figures as a basis of production in that particular State?

Mr. Hudson. It would not have the right to set aside any State order. If it were determined under this bill that some method or practice in the production of petroleum in the field constituted waste under the bill, the regulation would so define it. And that regulation might indicate a more restrictive production practice than was then indicated under the State law. And it would then be enforcible and would go into operation.

Mr. Wolverton. Would it have the effect of giving the Federal regulatory body the right, when it found waste to exist, to go into court and stop that waste, even though the State regulatory body would not be of the opinion that waste was being committed?

Mr. Hudson. That is possible under the bill.

Mr. Wolverton. Well, then, the fundamental purpose of this bill is to create a Federal authority in place of the State authority that now exists?

Mr. HUDSON. I don't think the bill is so framed as to make that possible. First, it does not have the scope; the functions under the bill are not as wide in their scope as I understand the State laws authorize to be exerted by those regulatory agencies. Where any possible conflict or disagreement might occur is solely in the application of the standard of waste, the physical waste as laid down in the bill.

Mr. WOLVERTON. I do not wish to imply that I have any particular viewpoint at this time as to the necessity for Federal control or whether the continuation of State control is sufficient; but I am anxious to know just what is the purpose of this bill with respect to Federal control as opposed to State control in the event that there is a conflict between the two as to what would be a proper amount of production.

Mr. HUDSON. Insofar as the Commissioner is authorized to issue regulations under the bill, my answer would be that those regulations would control if they were of a more restrictive nature than the regulations under State law. If they were not of a more restrictive nature, they probably would not be issued, because waste would not have been found in that respect.

Mr. WOLVERTON. Well, then, to that extent this bill does seek to supersede State control?

Mr. HUDSON. Seeks to complement it, at least, in that way.

Mr. WOLVERTON. I did not catch that.

Mr. HUDSON. It would serve to complement State control.

Mr. WOLVERTON. To complement? I can very readily understand it can complement if the two agencies have a harmony of thought, but I am more concerned as to what would be the power of the Federal Government to act in a case where the State regulatory body is not of the same opinion as the Federal regulatory body with respect to what is waste. Does this bill lodge the final authority in a situation such as that in the Federal agency?

Mr. HUDSON. It gives to the agency the authority to issue regulations which define or which set out waste which is occurring under this definition in the bill, and that regardless, I should say, of a particular State law on that point. In other words, the authority is not made dependent upon the State law.

Mr. WOLVERTON. You mean to leave the impression, then, that the purpose of this bill is to really supersede, when the necessity may arise, the judgment of the State regulatory body?

Mr. HUDSON. I am afraid I cannot answer you broadly as to the purpose of the bill, sir. I can only explain, as best I can, the authority that is given in the bill in the language used.

Mr. WOLVERTON. Well, to me that seems a very vital thing to clear up, as my reading of it, as I indicated at the beginning of my questioning, seems to show that there is a fear upon the part of some that this bill will supersede the State entirely in its control, and that it is placing in a Federal bureaucracy the power that now resides in the State. I am seeking to find out if there is justification for that criticism in the provisions contained in this bill; and, if not, what would you suggest to indicate that such is not the purpose?

Mr. HUDSON. I think on that estimate of the bill that witnesses following me will be more qualified to answer than I, sir.

Mr. WOLVERTON. It would seem to me, Mr. Hudson, that the person who drew the bill would have to have in his mind the object that he was seeking to carry out by the provisions of the bill and by the language that he used in expressing those provisions. I don't know of anyone who would be more capable of explaining to this committee the purpose of the bill than yourself, who drew it. Now, if you could suggest someone else who, in your opinion, would give me an understanding as to the purpose of the bill, I will defer my further questioning until that particular person comes before the committee.

Mr. Hudson. Having assisted in the drafting of the bill as a matter of legislative drafting, I can comment on the effect of the provisions that are contained. As to the purpose for the insertion of those provisions, I suggest that that can be more broadly explained by a later witness, and I think the Secretary, if I understand the question, will probably treat with that in his statement.

Mr. Wolverton. The reason I am inquiring as to this particular feature, the purpose of the bill, is because over a period of years starting with the first appointment of this committee, as a result of the introduction of the Thomas-Disney bill, there seemed to be a conflict as to how much authority should be given to the Federal Government and how much should be retained by the State. It also seemed that the States were of the opinion that they would be able to control the situation with some help from the Federal Government, but at no time did it seem that any State was anxious to relinquish any of its so-called sovereign rights. The original bill was not passed. A greatly modified bill was passed. During those hearings it appeared that a bill had been drafted in your Department known as the Margold bill, which was very extensive in its powers. That bill, however, did not come out into the direct light of day, nor was it offered as a Department bill, but it was something, however, that seemed to be in the background. I think it created fear as to what the intention of the Department was, particularly whether it was the intention to build up a strong Federal bureau that would supersede the powers theretofore exercised by the States. So that that question of the division of power between the Federal Government and the States on this important question has been a subject of many questions and much consideration by witnesses and by members of the committee.

It is because of that past history that I am anxious to know now, when this bill is presented, what is the real purpose of the bill. Has the operation under the Connally Act by the State regulatory bodies proved insufficient so that it requires additional power to be granted to the Federal Government, or just what is the reason or the purpose for this bill? What is thought to be accomplished by it that is not already being accomplished by the law as it is?

All of which, I think, is a vital matter. What is the purpose and object of this legislation now offered by your Department?

Mr. Hudson. Your question goes beyond my function with respect to the bill, and I cannot answer it as to the policies behind that, sir.

Mr. Wolverton. I will not pursue that line of questioning in view of what you have said. But my interest still remains, and I will seek to get an answer to it from some succeeding witness.

I notice that in section 2 you very definitely state that Congress hereby finds that in the production and storage of petroleum from the deposits situated within the United States, the employment of methods and practices which are wasteful of petroleum and of the reservoir energy available for the recovery thereof from such deposits (1) is inimical to the maintenance of reserves of petroleum, and of the facilities for the recovery and transportation thereof, available for military and supporting civilian needs in an adequate national defense, and so forth. Those findings that Congress by this bill states to exist are very important, I assume, in sustaining the constitutionality of this act, and I assume that is the reason that section 2 is put in there in that way; is that true?

Mr. HUDSON. That is correct; and it gives the purposes of the bill.

Mr. WOLVERTON. Then if section 2 goes to that fundamental necessity of sustaining the constitutional action of Congress, I assume, then, that the facts that will justify that finding will be produced to this committee?

Mr. HUDSON. Yes, sir. These statements, these findings, are an estimate of what is to be produced before the committee.

Mr. WOLVERTON. I also assume that your position as an attorney in the drafting of the bill does not enable you to speak with reference to the factual basis of those findings?

Mr. HUDSON. The factual basis; no, sir.

Mr. WOLVERTON. That is all.

Mr. COLE. Mr. Mapes?

Mr. MAPES. Mr. Hudson, as I understand it, briefly stated, this bill creates a Petroleum Administrator who is authorized to make an examination of all oil-producing fields in the United States; and if he finds that in his opinion wasteful methods of production are being pursued, it is his duty to issue rules and regulations to correct those wasteful methods; and then if anyone violates the rules and regulations which the Administrator promulgates, he has committed an unlawful act, which may be a crime; is that correct?

Mr. HUDSON. He is subject to the penalties; yes, sir.

Mr. MAPES. And the penalties are criminal penalties, are they not?

Mr. HUDSON. Yes.

Mr. MAPES. Are you a practical oilman, or did you only perform the mechanics of putting the bill together?

Mr. HUDSON. I merely did the legislative drafting, sir.

Mr. MAPES. You have not, then, an opinion based upon practical knowledge as to whether waste in the production of oil does exist or not?

Mr. HUDSON. No, sir.

Mr. MAPES. It would seem to me that two of the principal things for this committee to consider in connection with this bill are to determine whether or not there is unreasonable waste in the production of oil; and if there is such unreasonable waste, whether or not a set-up such as this bill proposes can correct that situation better than the State authorities and the industry itself can do it. Do you agree with that?

Mr. HUDSON. I think that is correct, sir.

Mr. MAPES. You are not able to enlighten the committee, as I understand you, because of your lack of practical information about the production of oil, as to whether or not there is waste now in the production?

Mr. HUDSON. No, sir; the witnesses who follow me will be qualified to do that.

Mr. MAPES. Mr. Wolverton referred to one issue of the National Petroleum News. Saturday afternoon I happened to be looking over the issue of November 1. It gave an account of the broadcasts over the radio during the summer about the conservation of our natural resources and particularly oil. Do you know how those broadcasts originated?

Mr. HUDSON. I do not have any connection with those.

Mr. MAPES. You have not had any connection with them; have no information about them?

Mr. HUDSON. No, sir; I do not.

Mr. MAPES. As a matter of procedure, in carrying out the functions of the Administrator, I would like to ask you this question: The Administrator is authorized to make complaints against any violators of his orders in the courts, and the findings of fact of the Administrator, if supported by substantial evidence, are to be accepted by the courts.

It is not clear to me as to whether that procedure is criminal or civil.

Mr. HUDSON. In going to the courts for restraining orders, injunctions, or writs of mandamus, in that civil proceedings, if the Commissioner has theretofore held a hearing, the facts found by him are, if substantiated by the evidence, conclusive.

Mr. MAPES. Yes. Is that a criminal proceeding?

Mr. HUDSON. No, sir; the Commissioner would not initiate the criminal proceedings.

Mr. MAPES. Suppose the Commissioner, for example, or the Administrator, found that any production of a well over 25 barrels a day was wasteful and issued an order to that effect, and the producer either with or without the consent of the State authorities produced 50 barrels a day; would the violation of such an order of the Administrator be a criminal violation?

Mr. HUDSON. Yes, sir.

Mr. MAPES. How would the violator be brought into court; through grand jury and the district attorney, the same as in other violations of Federal law?

Mr. HUDSON. Through the Department of Justice; yes, sir.

Mr. MAPES. What is the purpose of the civil procedure in the bill?

Mr. HUDSON. To permit the Commissioner to get enforcement of the regulations, or the orders, from the court in order to cut off the waste that is occurring.

Mr. MAPES. Anyone who violated the orders of the Administrator then could be proceeded against either civilly or criminally?

Mr. HUDSON. Yes; they can be proceeded against civilly in order to enjoin them.

Mr. MAPES. Is that civil procedure somewhat after the manner of the enforcement of the orders of the Federal Trade Commission?

Mr. HUDSON. I think it is, sir. These provisions as to procedure have been taken from other legislation now on the statutes. I cannot at the moment recall exactly the procedure followed by the Federal Trade Commission, but I could make an examination, a comparison between these provisions and other existing statutes, and submit that.

Mr. MAPES. Have you anything to say about the transfer of the Naval Reserves to the Department of the Interior; have you any practical information about that?

Mr. HUDSON. Practical information?

Mr. MAPES. Yes.

Mr. HUDSON. No, sir; I would just make this comment, that section 8, which provides that the provisions of this act shall extend to all deposits owned by the United States, would in that form apply to the Naval Reserves insofar as the scope of the bill is concerned. That is, the power to regulate production due to waste.

Mr. MAPES. You know that the Navy Department is opposed to that do you not?

Mr. HUDSON. I understand so, sir.

Mr. MAPES. Do you have any idea as to how large an organization the Administrator would have to have to make an investigation of all of the oil fields of the country, such as this bill contemplates?

Mr. HUDSON. No, sir; I do not. The authorization, of course, is to investigate those fields in such sequence as may be feasible. That provision bears on the question of how much organization would be required. It does not contemplate in that language that it should be done all at once.

Mr. MAPES. I have been spending part of my time during the recent extra session of Congress listening to the testimony on petroleum before the O'Mahoney Monopoly Committee.

My impression has been that there has been material improvement in the production of oil so far as the elimination of waste is concerned, during the last few years, or since the investigations by this committee 5 years ago. As far as I am concerned, I would like to know how much waste there is now in these different fields and to what extent the State authorities and the petroleum industry are able to handle the situation.

Mr. PEARSON. May I ask a question?

Mr. COLE. Mr. Pearson.

Mr. PEARSON. Mr. Hudson, when I interrupted you at the start of your testimony and questioned you about the discretionary power vested in the Commissioner under this act, the underlying thought back of that question was the same that prompted the questions just asked by Mr. Wolverton, and that was the concern that I felt about the administration of this law depriving the States of their regulatory powers and in effect superseding any action which the State regulatory bodies might heretofore have taken or might hereafter take in the event this becomes a law, and I want to direct your attention to section 5 of this bill, and if it is not asking too much, to ask you to give me your opinion, as a lawyer, of the effect of section 5, in section 5 (a) or (b) (1), where you define what waste is.

Mr. HUDSON. Yes, sir.

Mr. PEARSON. Both in (1) and (2). Then, in section (c) (1), you provide that—

> In making the determination required in subsection (a) of this section—

that is, in determining what shall be waste—

> the Commissioner shall consider for each field as a whole and for the several parts thereof, such information as may be obtainable—

as to porosity, permeability, and other characteristics of the deposit or deposits, and then you have a list of useful things which shall form the basis of the determination of what constitutes waste. Among those things I notice:

> (3) Well spacing, drilling practices, well casing, and well completions;
> (4) The rate of decline in reservoir pressure per unit of crude oil produced—

and somewhere in the list is a reference to the spacing of wells; method of completion of wells, and capping them and so forth.

Now, could there be any doubt, Mr. Hudson, about the fact that these things are to constitute the basis for the determination of a wasteful condition existing, that the Commissioner would have the power by mere regulation to supersede any contrary rule on the part of State regulatory bodies, if they were in fact in conflict with what the Commissioner felt constituted wasteful practices?

Mr. Hudson. I think I can best answer that by pointing out the provisions in 6 (b) on page 8, which directs the Commissioner, after conclusion of investigation and the finding that the methods and practices employed are not effective in preventing avoidable waste, directs then that he shall, by regulation, designate, and define with particularity those methods and practices which he shall find to be wasteful, that is, that he shall find to be wasteful with reference to the definitions in section 5.

Mr. Pearson. Yes.

Mr. Hudson. Now, in laying down and designating by regulation the method or a practice which the Commissioner has found to constitute waste under the definitions, if that, in effect, is different from or more restrictive than a State regulation directed to the same point, still the Commission's regulation would be enforcible under this bill.

Mr. Pearson. And the man who violated the Commissioner's regulation, even though he was complying with a State regulation, would become amenable to civil and criminal prosecution.

Mr. Hudson. If those two regulations hit to the same point and did not meet, that would be the case.

Mr. Pearson. That amounts, in substance and in short, to absolute nullification of any regulation which the State body might impose, if they conflict with the regulation of the Commissioner, does it not?

Mr. Hudson. If they in fact, differ in their standards from the standards laid down here.

Mr. Pearson. In other words, the standards fixed by the Commissioner would be controlling.

Mr. Hudson. The standards fixed in the bill, as applied to the facts found by the Commissioner.

Mr. Pearson. And section 6, to which you have just referred, almost amounts to vesting the Commissioner with the right to instruct the State regulatory bodies as to what they shall require them to produce, does it not?

Mr. Hudson. It requires him to make known to the State regulatory bodies what he has found.

Mr. Pearson. And if the State regulatory body does not change, the Commissioner then can prosecute the operators for violating his regulations.

Mr. Hudson. After the promulgation; yes, sir.

Mr. Wolverton. I would like to present a concrete case to you and ask what could be done under the provisions of this bill in such an event.

Last summer, I think during the month of August, one of the major oil companies reduced its price to the consumer. A hurried meeting was called of the different State regulatory bodies. To make a long story short, they dealt with the situation by shutting off all production in those States. The purpose would seem to be that by reducing production the price would be kept up to the consumer by creating an artificial shortage.

Now, in the event that the Federal agency was in operation and they deemed that contrary to the consumers' interest, what could have been done under the provisions of this bill to correct that situation?

Mr. HUDSON. Nothing under this bill, from my understanding of the situation.

The bill does not lay down any standard nor make any provision concerning economic waste, or on the question of prices or marketing in any of its phases. It is limited to the physical aspects of the production in the field.

Mr. MAPES. May I ask a question there?

Mr. WOLVERTON. Certainly.

Mr. MAPES. Suppose the Administrator, under a situation of that kind, found that closing the well down absolutely for 15 days would result in less oil being produced ultimately, could he not find that doing so was a physical waste and order them to pump again?

Mr. HUDSON. I am afraid I do not know enough of what may be involved, as a matter of fact there. I should say that his regulations would probably be directed to the manner of closing down wells in order to protect them.

Mr. MAPES. Let me put it this way: If he found that closing them down would result in less oil being produced, he could impose his regulations, could he not?

Mr. HUDSON. His regulations would have to be—you mean as to those regulations in effect at the time before closing?

Mr. MAPES. If he found that the closing down of the wells then for 15 days would actually result in less oil being produced out of the field eventually, he could issue regulations which would prevent their closing down or require them to pump again, could he not?

Mr. HUDSON. I think his regulations would apply to the method of closing. I do not think that they would apply to anything else.

Mr. MAPES. If closing them was going to result in physical waste eventually, he could prevent it by regulations, could he not, under the terms of the bill?

Mr. HUDSON. The Commissioner can issue his regulations only as to avoidable waste. The question which you have put is one that I am not certain of the answer.

Mr. MAPES. I am assuming in my question that closing them entirely would result in waste.

Mr. HUDSON. I think, though, that it might not be avoidable on the part of the operator if his well was closed by competent authority.

Mr. MAPES. Any regulation of the State authorities—assuming that the operator is a law-abiding citizen—would not be avoidable by the operator, so that that would not be true of violating an order to close down entirely any more than it would be true of violating any other order of the State authority, would it?

Mr. HUDSON. No, sir; I think not; any order of a State commission which in a particular case is more restrictive to the operators.

Mr. MAPES. Getting back to Mr. Wolverton's question, under this bill, assuming that closing the well for 15 days would result in ultimate waste, the administrator could, could he not, make a regulation which would require the operator to go ahead?

Mr. HUDSON. I think that is a difficult question, sir, of construction which has not come to my mind before, and I think it would be difficult to answer.

Mr. MAPES. It seems to me to be the very purpose of this law; not questioning the merits of it at all, but it seems to me that is what the bill does.

Mr. HUDSON. I am not certain how that particular case might be construed.

Mr. WOLVERTON. Mr. Mapes has brought the thought that I had in mind in asking the question. I think that question presents a situation that goes right to the heart of this bill, namely, as to what authority is being given to the Commissioner under the terms of this bill. It seems from your answer that there would be no doubt of the right of the Commissioner to act in the event that the order of the State regulatory body produced in the opinion of the Federal authority waste, physical waste; that then he could act; but where there is a shutting down completely, so that the question of waste might not appear on the surface, unless it did happen, as Mr. Mapes has indicated, then he would not have any authority to act.

Mr. HUDSON. He would not have any authority to act, at least——

Mr. WOLVERTON (continuing). So that the purpose of this bill is only to regulate production and has nothing to do with price control.

Mr. HUDSON. That is correct. There is no function as to that.

Mr. WOLVERTON. In other words, in the interest of the consumer, this bill has no provision whatsoever for a case of the kind that I have just mentioned.

Mr. HUDSON. It does not go beyond the physical aspect of the waste in production.

Mr. WOLVERTON. I have some further thoughts along that line, but I will reserve my questions until someone appears who will speak as to the policies. You are not speaking as to that at all.

Mr. HUDSON. No, sir.

Mr. COLE. That is all, Mr. Hudson. Thank you.

Mr. HUDSON. Thank you.

## STATEMENT OF HUGH D. MISER, GEOLOGIST IN CHARGE, SECTION GEOLOGY OF FUELS, GEOLOGICAL SURVEY, UNITED STATES DEPARTMENT OF THE INTERIOR

Mr. COLE. We will now hear Mr. Hugh D. Miser.

Mr. Miser, will you state your full name, present position, and give us a brief background of your training and experience.?

First, for the benefit of the record, Mr. Miser, is a geologist, United States Geological Survey, and he will bring up to date that part of the 1934 investigation covering, as I stated previously, pages 869 to 1,081 of part II.

All right, Mr. Miser, you may proceed.

Mr. MISER. My name is Hugh D. Miser, Arkansas is my home State; I have been connected with the Geological Survey of the Interior Department since 1911, when I took a civil-service examination for the position of geologist.

I have been in Washington since 1912 as a geologist of the Geological Survey and for the past 12 years I have been geologist in charge of the section of the Survey known as geology of fuels. These fuels include coal, oil, and gas.

I have thus responsible charge of the geological investigations of coal, oil, and gas deposits that are made by the Geological Survey.

I believe, Congressman, that if that is sufficient concerning myself, I may proceed with the report, if agreeable.

Mr. Cole. Are you a graduate of any university?

Mr. Miser. Graduate of the University of Arkansas.

Mr. Cole. What degree?

Mr. Miser. B. A. degree in 1908 and M. A. degree in 1912.

Mr. Mapes. Briefly, it is under you that the surveys of the reserves for oil, gas, and coal are made; is that correct?

Mr. Miser. Yes, sir. We make actual estimates of coal reserves. When it comes to oil reserves, and gas reserves, we do not have firsthand information for making such estimates, except in the fields where we are making geologic investigations. So therefore, for the country as a whole, we use available information from trade journals and other sources concerning the estimates of the individual fields, the several States, and the United States.

Mr. Mapes. Do your findings differ materially from the findings of the National Resources Committee appointed by the President?

Mr. Miser. I am familiar with that publication, Congressman. There is one chapter on petroleum reserves that was prepared by me in collaboration with Mr. Richardson and Mr. Dane.

The information given in that chapter is essentially the same as given in the new report in Congressman Cole's possession though the discussion of reserves has been brought up to date.

Mr. Mapes. Do you differ from the committee on its other findings?

Mr. Miser. I should like to inquire just what point you have in mind.

Mr. Mapes. I do not have any particular point in mind, except that I glanced through its report and I noticed it estimates that the coal reserves will last from 2,000 to 4,000 years, and petroleum about 20, and gas somewhat less. Do you agree with those general findings?

Mr. Miser. Mr. Hendricks, of the Survey, who works in my section, made the estimate that our coal reserves would last about 2,000 years. Our coal deposits are well known—the extent of the beds, the thickness of the beds, and the character of the beds.

Mr. Mapes. I do not want to examine you now, at the beginning of your statement, but I would like to have your judgment as to whether this report is a fairly accurate and reliable one.

Mr. Miser. Congressman, when it comes to estimating, in terms of years, how long our oil supply will last, I am unable to express an opinion, because we do not know.

Mr. Mapes. You do not want to give blanket approval to this report, as I understand you?

Mr. Miser. We have in sight now something over 17,000,000,000 barrels of oil, as of the 1st of January, if there were no new fields.

Mr. Mapes. Does that include the new field down in Mississippi that I read about in the paper yesterday?

Mr. Miser. That is the estimate as of the 1st of January. So, the new field in Mississippi and the reported field in Nebraska are not included in that reserve. It is my opinion that it is impossible to predict in terms of years how long our petroleum will last.

I do not believe that I would subscribe to 20 years. That is anybody's guess; anybody has a right to express an opinion. That is the opinion of whoever wrote that statement.

Mr. COLE. Mr. Miser, you were asked to bring up to date that part of the 1934 investigation covering, as I stated previously, pages 869 to 1081 of part II. That work, which was quite exhaustive, has been filed for printing in the hearings.

We would like to have such preliminary statement in introducing this work as you care to make before the committee asks you any questions.

Mr. MISER. Congressman Cole, I returned to Washington last night from an official trip and have not had an opportunity to prepare a formal statement, but since 9 o'clock this morning I have marked some pertinent paragraphs in my copy of the report; and if it is agreeable to you, I shall explain some of the features of the report and read a few pertinent paragraphs.

Mr. COLE. Very well. You may file the report at this time and then proceed as you have in mind.

Mr. MISER. The report in whose preparation I participated is entitled "Outstanding Features of the Oil Field Development and Petroleum Geology in the United States, 1934–38, by the Geological Survey, United States Department of the Interior."

Shall I read the names of those who prepared it?

Mr. COLE. Yes.

Mr. MISER. This report was written by H. D. Miser, with the collaboration of Paul Averitt, N. W. Bass, W. H. Bradley, C. H. Dane, A. M. Farrell, T. A. Hendricks, C. B. Hunt, P. B. King, W. G. Pierce, O. C. Postley, R. W. Richards, G. B. Richardson, and P. D. Trask.

The 5-year period of 1934–38 covered by the present report is a small portion of the life span of the petroleum industry in the United States; but, from comparison with like periods——

Mr. WOLVERTON. Mr. Chairman, may I make an inquiry as to the report?

Mr. COLE. Mr. Wolverton.

Mr. WOLVERTON. What period does this report that you have submitted to the committee cover, 1934–38?

Mr. MISER. That is correct.

Mr. WOLVERTON. What dates in 1938?

Mr. MISER. To the end of the year.

Mr. WOLVERTON. That is to the beginning of this present year?

Mr. MISER. Yes, sir.

Mr. WOLVERTON. As you go along, if there is any situation that has developed since the preparation of that report, it seems to me it would be appropriate for you to call the committee's attention to the facts. The resolution under which we are acting is a resolution to bring our previous report up to date. In the intervening years between the previous report and the present time, there may or may not have been important developments. If you have knowledge of any such, I think it would be proper that you call it to the attention of the committee.

Mr. COLE. Mr. Miser, is it a fact that the best available statistics as to reserves, for instance, are those as of January 1, 1939? Do you have any since that date that are very reliable or authentic?

Mr. **Miser**. The estimates that are given for the country as a whole are those for the 1st of January, 1939.

Mr. **Cole**. Yes.

Mr. **Miser**. Those estimates are embodied in this report, and there are some estimates available for the first half of 1939; I recall that in this report there are some estimates given for Illinois for the first half of 1939.

Mr. **Cole**. Then we can assume that on January 1, 1940, you will have the statistics for the current year and can bring those figures up to date?

Mr. **Miser**. Yes, sir.

Mr. **Cole**. The hearings will not be concluded by that time, and I think that you should, as Mr. Wolverton has suggested, in a subsequent report to the committee change any statements that you might have in this report so as to make it as of January 1, 1940.

That can be done very easily.

Mr. **Miser**. That can be done very easily, if you will just let me know a little while before this report goes to press.

Mr. **Cole**. This will go to print now, and then you can, by supplemental report, after January 1, furnish that information.

Mr. **Miser**. Yes, sir.

Mr. **Mapes**. Mr. Chairman, if this is going to print now, I would like to call the witness' attention to one very important omission so far as Michigan is concerned.

In a hasty glance at your report, I notice this statement referring to the Michigan field:

> The most productive fields are now in Muskegon, Midland, Montcalm, Isabella, Gladwin, Clare, Ogemaw, Arenac, Allegan, and Van Buren Counties

In the report you have failed to mention Kent and Ottawa, in the Fifth Congressional District, where a great deal of oil is being produced right now. They are developing a field there, a great deal of it this year—some of it last year, but most of it this year.

Mr. **Miser**. I am very sorry, but there was not an opportunity to bring this report right up to date since the first of 1939 as we would like to have done.

Mr. **Mapes**. As a matter of fact, I think I am correct in my recollection that the newspapers—Michigan papers—have been saying that more permits have been granted by the State authorities to put wells down in those two counties in the last few weeks than in any other section of the State.

Mr. **Miser**. I am very sorry that that omission has taken place; but we have not had an opportunity to bring it up to the present.

Mr. **Mapes**. I suppose in fairness to you, I should say that a great deal of that development has been since the 1st of January 1939.

Mr. **Miser**. Those developments will be summarized in the supplemental report for 1939.

Mr. **Cole**. All right, you may proceed.

Mr. **Miser**. The 5-year period of 1934–38 covered by the present report is a small portion of the life span of the petroleum industry in the United States; but, from comparison with like periods, not only is the production of the last 5 years the greatest, but the known reserves of petroleum have reached the highest figure in the history of the industry. This report describes briefly the oil-field developments, oil production, reserves, geologic features of productive areas, and oil possibilities of many areas that were being actively explored during the 5-year period. It supplements sections 6, 8, and 9 of the Geological Survey's report on Geology and Occurrence of Petroleum in the United States, which was prepared in 1934 for the subcommittee of the Committee on Interstate and Foreign Commerce of the House of Representatives, Seventy-third Congress.

Mr. Wolverton. What page is that on?

Mr. Miser. Page 4, top of the page.

Some of the chapters in the report being submitted today are: Production of petroleum, imports and exports, reserves, current methods employed in petroleum geology, deep drilling, condensate pools, offshore marine production, and then these chapters are followed by the State summaries which give the outstanding features of oil-field development and petroleum geology during the 5-year period. The Geological Survey will submit a supplement later bringing the State summaries up to date, if that is your wish.

Mr. Cole. That is right.

Mr. Miser. But very briefly.

Mr. Cole. Yes.

Mr. Miser. Perhaps it would be well to comment at this time a little more fully concerning production and the reserves.

Mr. Cole. Before you get too far into the report I have a few questions.

Referring to table 2, page 8, do you have that before you?

Mr. Miser. Yes.

Mr. Cole. Fitts pool, Oklahoma, item 9, and Rodessa, item 7.

It is noticed that production in Fitts rose sharply from about 7,000,000 barrels in 1935 and to about 20,000,000 barrels in 1936 and to 31,000,000 barrels in 1937 and then dropped nearly 50 percent in 1938, to about 17,000,000 barrels, and that production in the Rodessa field rose from about 1,000,000 barrels in 1935 to 22,000,000 barrels in 1936.

The Fitts pool in Oklahoma, to which I have just referred, and the Rodessa field in Louisiana were mentioned in recent hearings to which Mr. Mapes has referred, as poorly controlled fields.

I would like to have your opinion as to whether it is a fair deduction from these figures given us that the sharp advance in production in the Fitts field in 1936 and 1937 and the abrupt decline in 1938, and the rapid development of the Rodessa in 1936 would tend to support the statement that production in Fitts and Rodessa fields has been poorly controlled.

Mr. Miser. The Geological Survey has no first-hand information of those two fields, and I thus have no information on which to answer your question.

Mr. Cole. On table 4, estimated petroleum reserves of foreign countries—that is found on page——

Mr. Miser. Ten.

Mr. Cole. Yes; table 4. You will note the figures for Venezuela and Colombia crude. Do the reserves in the fields of those two countries include those to which pipe lines to the seacoast have been recently completed?

Mr. Miser. This is an estimate which was made——

Mr. Cole. I am asking this for information of the committee generally and especially for one distinguished member of the committee who I hope shortly will visit Venezuela and Colombia.

Mr. **Miser.** Those estimates were made by Messrs. Garfias and Whetsel as of January 1, 1939, and it is my understanding that they include the reserves of fields in those countries, irrespective of pipe lines.

Mr. **Cole.** Has the Federal Government any present means of obtaining direct information on the petroleum reserves of foreign countries, or any way of checking the accuracy of private estimates, such as the one cited here? Do you have any machinery to do that?

Mr. **Miser.** Not in the Geological Survey.

Mr. **Cole.** Or anywhere that you know of?

Mr. **Miser.** I do not know of any.

Mr. **Cole.** Are you familiar with the bill before us?

Mr. **Miser.** I am familiar with it.

Mr. **Cole.** If that bill were in operation, you would have such authority, would you not?

Mr. **Miser.** Yes.

Mr. **Cole.** The Federal Government would have such authority?

Mr. **Miser.** Yes, sir.

Mr. **Cole.** Mr. Miser, does the Federal Government attempt to estimate the petroleum reserves of the United States; and, if not, what information, or upon what information, do you rely in order to make the statements you have in this report, such as are found in table 5? Do you estimate the private reserves of petroleum in this country? Does our Government have any estimates of its own of reserves?

Mr. **Miser.** I think the latest estimate that was made on the authority of the United States Government was the one by Mr. H. B. Soyster, of the Geological Survey. That was made for your committee in 1934. Since then we have made no estimates of petroleum for the country as a whole.

Mr. **Cole.** Of course, what I mean is as a regular function of our Government. We have not any machinery as one of the regular functions of the Federal Government, to currently determine or estimate the petroleum reserves of the United States.

Mr. **Miser.** We do not, except in the areas where the Geological Survey makes intensive investigations of oil fields. We have very few geologists working on that line.

Mr. **Cole.** Without that as a regular function of our Government, upon what information do you rely now in making your estimates?

Mr. **Miser.** We rely on estimates that become currently available in the Oil Weekly, the Oil and Gas Journal, and other journals, and through the American Petroleum Institute, and individuals.

Mr. **Cole.** Does the American Petroleum Institute maintain sources of information as to reserves and publish them in their annual reports?

Mr. **Miser.** Their estimates are prepared carefully, so far as I am aware; doubtless estimates of many individuals, and of the trade journals are also carefully prepared; but the American Petroleum Institute's estimates are prepared with the official sanction and authority of the management of the Petroleum Institute and perhaps—I do not know that I am correct in this—perhaps more geologists and engineers participate in making that estimate than the other estimates.

Mr. **Cole.** Do you know how their estimates are made?

Mr. **Miser.** I know a number of geologists who are on the committee for the estimation of petroleum reserves. I have talked with those geologists, and have learned from them briefly how they go about it.

The geologists are Frank Clark, of the Ohio Oil Co.; Clark Gester, of the Standard Oil Co. of California, and Fred Lahee, of the Sun Oil Co. I perhaps have talked with one or two others.

The United States is divided up into districts and the job of estimation of petroleum reserves of the different districts in the United States is parceled out to a number of individuals—the number I do not know, though I do know that some 50 or 60 geologists and engineers get this material together.

The Institute has a certain policy, or certain rules, to guide in the preparation of the estimates. The individual estimates are brought together, and I understand they are examined very carefully. Sometimes, I am told, the engineers and geologists are requested to follow more closely the guiding criteria and revise their estimates.

Mr. Cole. Is that work and the figures you speak of, for the American Petroleum Institute, made available to the Geological Survey and other departments of the Government?

Mr. Miser. The details of the estimates by the American Petroleum Institute are, so far as I know, not made available to any department of the Government and none of the basic data are made available, so far as I am aware.

Mr. Cole. So that in estimating the reserves of petroleum in the country today or as of January 1, 1939, as it is done, you rely entirely upon the reports of the Petroleum Institute and some other agencies, but principally the Petroleum Institute?

Mr. Miser. That is correct.

Mr. Mapes. Mr. Chairman, may I ask a question before the witness resumes reading from his statement?

Mr. Cole. Mr. Mapes.

Mr. Mapes. Am I right in my impression that the amount of the estimates of petroleum reserves has been materially increased in the last year or so, so that now some estimates are as high as 22,000,000,000 barrels?

Mr. Miser. I have not seen any printed statement to the effect that there is twenty or twenty-two billion barrels of oil in sight at the present time or as of January 1, 1939, but I have heard that there is such an estimate.

Mr. Mapes. I had in mind that I had seen a statement to that effect recently.

Mr. Cole. The committee will stand in recess until 2 o'clock.

(Thereupon, at 12:45 p m., the committee took a recess until 2 p. m. of the same day.)

## AFTERNOON SESSION

The committee was called to order at 2:20 p. m. by Mr. Cole.

Mr. Cole. The committee will come to order.

I notice Representative Disney, of Oklahoma, and Representative Beckworth, of Texas, in the room. We are very glad to have you gentlemen here, and if you want to say anything to the committee, we would be very glad to have you do so without further waiting.

Mr. Beckworth. A little later on in the hearing I would like to be heard; not today.

Mr. Disney. That is my position thus far.

## STATEMENT OF HUGH D. MISER—Resumed

Mr. Cole. Dr. Miser, do you know to what extent the increase in reserves has been due to new discoveries and how much of the addition is based upon an expectation of higher ultimate recoveries through the continued application of the methods of production control now in effect in many of the States?

Mr. Miser. The increase in reserves is due in part to the discovery of new fields and deeper producing zones. It is due in part to extensions of known fields.

Now, relative to any increase in reserves through development in technology, I am unable to answer that question. There are developments along many lines, and that would naturally affect the reserves. To express those things concretely in percentages, I would be unable to do. It might be difficult for anybody to do it.

Mr. Cole. In the report from the Navy Department, which will be before us on Wednesday, is found this statement [reading]:

> This backlog or producible reserve of oil has gradually accumulated over the past life of the industry as a result of many discoveries each year of relatively shallow (500–5,000 feet) producing areas capable of producing at a slowly diminishing rate over a relatively long period of time. Of late years, however, new discoveries of this type have fallen far below the annual rate of consumption of petroleum and our reserves have been maintained and augmented by discoveries of deep-seated (5,000–15,000 feet) oil horizons, many of which have been found within or adjacent to the known shallower fields. What the life of production from these deep sands will be is not yet known, but it would seem to be beyond question that production from them will be progressively shorter lived with increasing depth.

And this is the sentence I want to direct your especial attention to, and still quoting from the Admiral's statement:

> In my opinion, such deep production will add materially to the oil reserves of the United States but will not add at all to the life of the industry, as it is probable that all deep wells will have ceased production due to higher operating costs before some of the shallower wells now producing have yielded the last of their recoverable oil.

I want to know if you agree with that opinion or not?

Mr. Miser. It is true that deep wells add additional reserves. Many fields that are discovered in recent years are of shallow depth; for example, the Illinois fields.

It would take a little study to look into that question. The average depths of the producing wells as given in Petroleum Facts and Figures and in the trade journals have not increased so very greatly. But the maximum depths for wells have increased greatly. The deepest producer is something over 13,000 feet in Louisiana. So I would hardly feel competent to answer that question, Congressman.

Mr. Mapes. May I make sure that I understand you? While there are exceptions, as you say, where the depth goes down as far as 13,000 feet, that is an unusual case, as I understand it, and the average depth now is about the same as it has been; is that what you were saying?

Mr. Miser. It is only a matter of hundreds of feet more than it was, say, 20 or 30 years ago.

Mr. Mapes. My recollection is that the wells near Grand Rapids, Mich., are from 1,800 to 2,000 feet; is that your understanding?

Mr. Miser. Some Michigan wells are that depth and others are deeper. I do not remember the different localities for the different depths.

Mr. Cole. Dr. Miser, will you refer to page 95 of your report, where you are discussing the Moore pool in Oklahoma? You quote this language down about the sixth line:

> This wasteful practice depleted the natural reservoir pressure, and as a result the wells soon produced large quantities of water.

Do you know whether the Oklahoma Corporation Commission took any action to prevent the waste of gas and the depletion of reservoir pressure in the Moore pool, to which reference is made as I have just quoted?

Mr. Miser. No, sir.

Mr. Cole. You don't know whether they did or not?

Mr. Miser. No, sir. I have heard about the claims of great volumes of gas coming from the pool.

Mr. Cole. What is the source of your information?

Mr. Miser. I learned it from other geologists, and also I noted it in the trade journals. As to what was done to stop it, I don't know.

Mr. Cole. Do you know the nature of it as to the pressure drop, or anything of that kind?

Mr. Miser. No more than is given in this description of the Moore pool, which was written by Mr. N. W. Bass, who is stationed in Tulsa.

Mr. Cole. But the Federal Government has no authentic information on that except what you gathered from the geologists here and there?

Mr. Miser. I don't know of any.

Mr. Cole. All right. Now, Mr. Wolverton.

Mr. Wolverton. Dr. Miser, does the report which you have submitted to the committee today give an estimate of the present recoverable oil supplies of the United States?

Mr. Miser. The report which is submitted today quotes the currently available estimates, and there is no new estimate prepared and inserted as a part of this report.

Mr. Wolverton. What are the figures of the estimate you have presented to the committee?

Mr. Miser. The estimates as of January 1, 1939, range from 14 to 17½ billion barrels.

Mr. Wolverton. What was the estimate of known recoverable oil when you testified before this committee in 1934?

Mr. Miser. In 1934——

Mr. Cole (interposing). What page is that now you are reading from; what page of the report, Dr. Miser?

Mr. Miser. Mr. Soyster gave an estimate at that time. It is No. 12 on page 12; 13,360 billion barrels as of January 1, 1934. And then there was another estimate at the same time by the Petroleum Administrative Board that was issued in December 1935. That estimate was 10,638 million barrels.

Mr. Wolverton. In other words, there has been a very substantial increase in the known recoverable oil supply of the United States?

Mr. Miser. Yes, sir.

Mr. Wolverton. How do you account for the fact, then, that this bill is based fundamentally upon conservation?

Mr. Miser. Congressman, that is a difficult question for me to answer. I am a geologist in the Geological Survey and have had nothing to do with the drafting of this bill, and I do not have any knowledge concerning the policy or objectives for which it is drafted.

Mr. WOLVERTON. Well, this committee has had presented to it a bill which, in the opinion of some, if we are to judge by the opinions that have been expressed, is rather drastic in its terms. Whatever justification there may be for a bill of that character must, from a national standpoint, be based upon this appeal for conservation. This bill in its opening phrase and the title states, "to promote the conservation of petroleum" and continues, "to provide for cooperation with the States in preventing the waste of petroleum"; and then in section 2 it expresses the thought that Congress finds it to be in the national interest from the standpoint of national defense, and so forth, to provide means of conservation.

That being the basic principle of the bill, it seems to me that it is highly important that the committee should have presented to it facts that will show just what our known reserves are, whether they are increasing, whether they are decreasing, whether the method of recovery is improving to such an extent that it is indirectly increasing the number of recoverable barrels, whether the finding of new fields has come from improved methods of detecting oil beneath the surface, and whether in the face of all those elements taken together there is created a situation that makes the necessity for this bill more apparent at the present time than at any time in the 5 years we have been giving consideration to this subject?

In an endeavor to find that basic information, I asked you what estimate you gave in your present report as to the recoverable oil reserves of the United States; and you have said that it ranges, according to the authorities that you have consulted from 14 billion to 17½ billion?

Mr. MISER. Yes, sir.

Mr. WOLVERTON. Five years ago, it was only 13 billion, according to one authority, and 10 billion according to another to whom you have referred; indicating that, notwithstanding the increased use of crude oil and its derivatives that you have emphasized in your report, there are more known oil reserves and consequently more oil in the country today than there was 5 years ago. Now, if that be true, then I would like to know why we have this bill that emphasizes conservation and provides methods, that create the charge that it is drastic in character?

Mr. MISER. Although the reserves at the present time are the greatest in the history of the industry, the United States is producing and consuming a little more than half of the world's oil production. Furthermore, the United States according to our best information possesses about half of the known reserves.

The amount of oil that is in the ground, as we all know, is limited. When one field is found, that reduces by one the number of fields to be found, and when a barrel of oil is taken out of the ground, there is a barrel less to be taken out of the ground. So it behooves us, it seems to me, to practice conservation at all times.

But relative to your question, whether the case requires drastic action now in relation to 5 years ago or some other period, I do not believe I am qualified to express any opinion.

Mr. WOLVERTON. The reason of my inquiry is this: That each bill of this character that has been presented to the committee has always been on the basis of conservation, and each time some witness testifies almost identically as you have at the present time, by saying that the supply is limited and when you take one barrel out you have one barrel less.

Mr. MISER. Yes.

Mr. WOLVERTON. Now, theoretically, if you did not inquire any further than that, and if you had a fixed supply, that would be true. But the testimony before this committee has developed that, over a period of years there has been a gradual increase in the known reserves of oil in this country. Now, if the facts showed that, instead of increasing, it was decreasing, then there would be force and effect to your statement that when you take a barrel out there is one barrel less. But the net result has been over a period of years that there has been a very considerable increase of oil reserves in this country.

I have before me a statement made by Mr. E. O. Thompson, member of the Texas Railroad Commission and chairman of the compact commission, immediately after he left a conference with the President on October 18, as appears by an Associated Press account. It is headed, "President told that the reserve is ample," and Mr. Thompson, and with him at the time was Mr. W. J. Harraway of Oklahoma City, Oklahoma's representative, is reported to have said, and I am reading now from the news report:

> Thompson said they reported there was now a reserve of 17,500,000,000 barrels of oil, compared with 5,500,000,000 in 1925, and that the reserves were being increased.

That is a very considerable increase since 1925. It is practically 300 percent, and that is in the face of the increased use that has occurred during that period.

Now, if that fact be true as stated by Mr. Thompson, and I have no doubt he stated what he believed to be the fact, it would seem to me that it goes toward showing that the necessity for this kind of legislation does not exist actually as much as it does as a thought in somebody's mind. And if it is not necessary for a conservation purpose, then for what purpose is this kind of legislation being urged?

Mr. MISER. Of course, with the increased estimates in reserves, there has been increased demand. You may not have had an opportunity to see the chart which is in the report, Congressman; but that shows an increase in reserves over the period that Colonel Thompson speaks of.

Mr. WOLVERTON. Yes. So that your report agrees, then, with the statement which was made by Mr. Thompson, to which I have just directed your attention?

Mr. MISER. Concerning the increase in reserves; yes.

Mr. WOLVERTON. The table to which you have directed my attention shows a curve distinctly upward. I assume that the use of oil would show a curve upward. Would the use of oil during the same period show an upgrade?

Mr. MISER. Yes, sir; it does, somewhat.

Mr. WOLVERTON. As between the two, what comparison can you make? Has the known reserve increased greater than the increase in use?

Mr. MISER. I do not believe I could answer that question. That would take a good deal of computation, and it would depend upon whose estimates of reserves you would take as a basis for computation.

Mr. WOLVERTON. Well, I will come to that question in a minute. I think that is a highly important matter. But could you tell me this—and if you have not figured it out in your report, maybe somebody will at a later date—on the basis of our known reserves as compared to our use, for how many years would it be a sufficient supply?

Mr. MISER. In other words, if they would quit finding oil today?

Mr. WOLVERTON. Yes; and on the basis of rate of present use.

Mr. MISER. How long would the present reserve last?

Mr. WOLVERTON. I beg your pardon?

Mr. MISER. In other words, if they quit finding new oil fields, how long would the present reserves last?

Mr. WOLVERTON. Yes; based on the present consumption.

Mr. MISER. Well, there are about 17½ billion barrels in sight, and the consumption is a little less than a billion and a quarter. Except for the first few years oil could not be produced at that rate. Thus, in the course of a few years a shortage in oil would be faced.

Mr. WOLVERTON. How many years would you estimate?

Mr. MISER. There would be a shortage in petroleum in a very few years.

Mr. WOLVERTON. Well, whatever may be the difficulties, I am assuming that they would be taken into consideration. I was merely asking for an expression of an opinion from you—on the basis of the known reserves and the known consumption, how long in your opinion would it last as of the present date?

Mr. MISER. That is a rather difficult question. We know, in the first place, Congressman, they are not going to quit finding oil today or tomorrow. They are going to find oil as long as we live and our children live, and even their children.

Mr. WOLVERTON. What I am trying to get from you is an expression of an opinion.

Mr. MISER. It would be a guess, and based on a hypothetical situation which will never exist.

Mr. WOLVERTON. Well, all right. Here is what I am endeavoring to find out from you: If you know the known reserves now and the consumption each year, there certainly must be a figure that you could arrive at as to how long the supply would last at the present rate of use.

If you gave me that figure, then I would next ask the same question with respect to the known reserves in 1935, and the known consumption at that time. How long would it have lasted then?

Mr. MISER. There doubtless are some individuals who have figured along that line, but I never felt it profitable to do so, because it sets up a hypothetical case which really does not exist. Illinois reserves have increased 100 percent since the 1st of January of this year.

Mr. WOLVERTON. On that theory it would be more favorable and for the better over a period of these last few years, instead of for the worse?

Mr. MISER. We do not know how long the proved reserves of petroleum will increase over what they are now. To me it seems the real question is, How long we can continue to increase the reserves or maintain them at their present level?

Mr. WOLVERTON. Well, we do know that now there are three times as much known oil in the pools located in the United States than there was in 1925?

Mr. MISER. Yes, sir.

Mr. Wolverton. So that over that period of years there has been an increase from new discoveries and new methods of recovery and other technical features that have probably had something to do with our petroleum reserve figures?

Mr. Miser. Yes.

Mr. Wolverton. Is it your opinion that over a period of years we may still expect that increase?

Mr. Miser. I would be greatly disappointed, and I am sure the consumers and the industry would be, if it did not continue for a while.

Mr. Wolverton. So that our oil reserves for the future will increase, probably, through new discoveries, as they have in the past?

Mr. Miser. Surely; for an unknown period.

Mr. Wolverton. Judging by the past, are you of the opinion that the recoverable amount will be increased by improved methods?

Mr. Miser. That is my belief.

Mr. Wolverton. Is it your feeling that there might be an increase in the future as a result of improved methods of discovery?

Mr. Miser. I think there will be, to meet the expected increased demand.

Mr. Wolverton. I mean with reference to the discovery of new sources of oil in the ground. Now that they are using more scientific methods than in the past for discovering new oil fields are you not willing to assume that in the days ahead there will be even more improved methods of discovery that will add greatly in the discovery of new pools?

Mr. Miser. I believe so.

Mr. Wolverton. Are there improved methods in refining that enable us to get more from the oil that is taken from the ground today than in the past?

Mr. Miser. Such methods increase our reserves.

Mr. Wolverton. Well, that is likewise a possibility in the future?

Mr. Miser. Yes, sir.

Mr. Wolverton. Is there a possibility that improvement in machinery will give more energy for less oil than has been the case in the past?

Mr. Miser. We believe all those things, Congressman; but although we believe them, they are not the same as real assurance. We cannot count on that; we look forward to that.

Mr. Wolverton. Based upon the experience of the past, it would seem to me we have a right to take all these elements into our calculations for the future?

Mr. Miser. I would confidently predict developments along all the lines which you mention.

Mr. Wolverton. Now, coming back to the basic figure, as to how much oil there is in the ground, it astonishes me today, as it did 5 years ago, to learn that our Federal Government does not on its own initiative make any examination or survey to determine what is the oil reserve of our country. If I understand you correctly, you only make such studies in fields where there is some geological research going on?

Mr. Miser. We do it in some areas where there are public lands owned by the Government, and we do it in some areas where we are making a study of the oil fields.

Mr. **Wolverton**. Well, the study you make in this limited number of fields certainly does not enable you to arrive at any figure as to the total amount that is in the United States?

Mr. **Miser**. It does not.

Mr. **Wolverton**. You depend upon the figures that you obtain from sources that you consider reliable?

Mr. **Miser**. Yes, sir.

Mr. **Wolverton**. In the obtaining of the figures from the American Petroleum Institute, or from any other source, do you accept the figures that appear in their publications, or do you submit a questionnaire to them that requires sworn statements, or do you examine the individuals who make up the estimates for them; or does the Government just say, "We will take that as the figure and let it go at that"?

Mr. **Miser**. The Geological Survey makes use of the estimates as they appear from time to time in trade journals and other forms of publications.

Mr. **Wolverton**. Just the same, as I took my figures a moment ago from a newspaper report in one of our Washington papers?

Mr. **Miser**. This matter of estimation of reserves, Congressman, is so far as I know, something that requires close touch with the different fields. The company geologists and the company petroleum engineers, who have watched the development of a field and have kept in touch with it during the entire lifetime of the field, are in a position to give some real information on the estimates of reserves in that field.

Mr. **Wolverton**. Well, is it not your opinion that the Federal Government should have individuals in those fields making that same kind of a study that you say is made by private interests?

Mr. **Miser**. You mean, in all the fields of the United States?

Mr. **Wolverton**. I mean, in all of the fields of the United States, that is, if you are going to ask for legislation based upon the need of conservation?

Mr. **Miser**. There are in the United States somewhere between 2,500 and 3,000 petroleum geologists employed by oil companies, and they spend their lifetime studying the fields and looking for new reserves of oil. It is my belief that the United States Government, if it desires to obtain complete knowledge concerning all the fields in the United States through its own geologists and engineers, will require a staff of geologists and engineers many times greater than now on the Government pay roll.

Mr. **Wolverton**. Well, it would seem to me that we have gotten used to that now.

What I have in mind is this: That with this important matter, that has to do with national defense and our economic future, that justifies a Department of the Government coming before a committee of Congress and asking it to report favorably upon a bill of this character, the sole purpose of which is to conserve a natural resource that all will agree is limited, it would seem to me that the Federal Government ought to be in a position to speak definitely on that important matter, and not have to depend upon advice or figures that are given by some individual not in the Government service.

Mr. **Cole**. Mr. Wolverton, might I interrupt to state that it is my understanding there is little authority in the Government now to do the very thing you referred to, but under this legislation they would have ample authority.

Mr. Wolverton. Is that your feeling, Doctor, that it could be done under this legislation?

Mr. Miser. In our limited way, we make estimates of reserves in some fields. We have that authority in the organic act of the Geological Survey.

Mr. Wolverton. Well, if this bill gives the authority that the chairman suggests—and I assume he has read it and studied it carefully enough to express that opinion—I will say that is to my mind, a mighty good feature of the bill, if that is in it.

Mr. Miser. I understand that feature is in it. I have read the bill, and I heard Mr. Hudson explain it this morning.

Mr. Wolverton. I wish some time we could have before us information from a Government official who will say, "Our study shows us that it is so and so, and so and so, and we know the facts," and not, as we have heard for 5 years, witnesses come and say, "well, there are so many barrels of oil, the basis of my information is some reports I have read, issued by the American Petroleum Institute, or somebody else, or somebody else." I think the matter is so important that it requires definite information on the part of the Federal Government to justify this kind of legislation.

Mr. Miser. To me, that type of information would require some time and also a great force of geologists and engineers. In addition, they would have to go to the company officials to get much of the required information.

Mr. Wolverton. I think authoritative information of that kind would not only be helpful but necessary to the Government itself, and certainly it would be helpful from the standpoint of the consuming public, because as soon as you limit production you regulate the price to some extent, and thus it has a direct relationship to the price that is charged the consumer. Now, if there is enough oil in the United States that legislation of this kind is unnecessary, then the consuming public would get the benefit of it by increased production. If it does not exist, then they are very much interested to see that the production is decreased so that there may be longer use. It has, therefore, not only a direct bearing on the function of the Government itself but on the welfare of the consuming public. That is the reason I think there ought to be definite information from a Government source.

Mr. Cole. Mr. Wolverton, I might interrupt again to say that in the O'Mahoney committee investigation quite a lengthy questionnaire was sent—I expect to almost every oil-producing company in the United States—and one of the questions, one of the principal questions, dealt with the known reserves. I have asked them for a recapitulation of all that data when it is available. I was advised that within the next few weeks that information would be released.

Mr. Wolverton. That will be very helpful.

Mr. Cole. That will be, I think, the first authentic—I started to say "reliable"—but the first Federal agency with the authority of law back of it to determine in one way at least the very thing you had in mind.

All right, sir, you may proceed, Doctor.

Mr. Miser. Some of the things that have just been discussed I may go into very briefly, if I may read a few paragraphs I have indicated.

The great volume of the present domestic production is strikingly illustrated by the fact that the total output of petroleum during the 5-year period 1934–38 was 5.5 times greater than the total output—1,000,000,000 barrels—from 1859 to 1900. The present year, 1939, will probably witness the production of the twenty-second-billionth barrel of oil. Twenty-two States have supplied the total output, amounting to 21,187,141,000 barrels through 1938.

And, as I remarked this morning, the newspaper reports indicate that Nebraska has been added to the list of producing States, oil having been found last week near Falls City.

Texas ranks first among the States, having produced a quarter of the total output of oil; California ranks second, with 24 percent; and Oklahoma is third, with 21 percent. The total production of each of these three States is greater than that of the U. S. S. R., a little less than 4,000,000,000 barrels through 1938, which ranks next to the United States in cumulative production of petroleum.

Of the world's output of oil in 1938—1,978,000,000 barrels—61 percent—that is, 1,213,000,000 barrels—came from the United States. A similar proportion—57 percent—of the world's consumption of petroleum products and related fuels in 1938 was consumed in the United States.

Although the United States produces and consumes three-fifths of the world's oil, its known reserves are about equal to those of the rest of the world. The reserves in the United States at the beginning of 1939, as I stated——

Mr. **Cole** (interposing). Did you just read "three-fifths"? I understood you to testify this morning it was about 50 percent of the total consumption of oil, and three-fifths is nearer correct: is it not?

Mr. **Miser**. The United States consumed——

Mr. **Cole**. You just read it there.

Mr. **Miser**. Although the United States produces and consumes three-fifths of the world's oil—that is about 60 percent.

Mr. **Cole**. Yes. You said this morning it was about 50 percent, in your testimony.

Mr. **Miser**. We possess about half of the reserves.

Mr. **Cole**. I understood you to say this morning that we consume 50 percent.

Mr. **Miser**. I was in error if I made that statement.

Mr. **Cole**. Maybe I am mistaken, myself, about it.

Mr. **Miser**. As I stated a few moments ago, the reserves in the United States at the beginning of 1939, according to the different estimates, ranged from 14 to 17½ billion barrels, whereas the reserves in foreign countries amounted to 17.9 billion barrels.

The known reserves of petroleum in the United States at the beginning of the 5-year period 1934–38 were placed at 13.3 billion barrels by H. B. Soyster, of the Geological Survey; and at the end of the period, January 1, 1939, they were placed at 17.3 billion barrels by the American Petroleum Institute. On the basis of these 2 estimates, the known reserves of petroleum increased 4,000,000,000 barrels in the 5 years since January 1, 1934, in spite of the production of 5.5 billion barrels in that period.

About three-fourths of this increase of reserves has occurred in Texas, but other States with notable increases include Arkansas, Illinois, Kansas, Louisiana, and New Mexico. The several States whose reserves exceed 3 percent of the country's total, as given by the American Petroleum Institute for January 1, 1939, are:

| | Percent | | Percent |
|---|---|---|---|
| Texas | 54.5 | Louisiana | 6 |
| California | 18.4 | New Mexico | 4 |
| Oklahoma | 6.7 | Kansas | 3.5 |

And since the first of the year we have information that reserves in Illinois have doubled.

An examination of the graphic representation of the Nation's known reserves, shown on figure 1, reveals the fact that the increase in reserves for the 5-year period 1934–38 has about equaled that for many preceding years. The estimate of 5,000,000,000 barrels of oil "in sight" in 1922 and Soyster's estimate of 13.3 billion barrels for January 1, 1934, indicate an increase of 8.3 billion barrels for this 12-year period, equal to an annual increase of about 0.7 billion barrels. On the other hand, the increase of 4,000,000,000 barrels in reserves for the 5-year period 1934–38, indicated by the estimate of 13.3 billion barrels by Soyster for January 1, 1934, and the estimate of 17.3 billion barrels by the American Petroleum Institute for January 1, 1939, is equal to an annual increase of 0.8 billion barrels, a little higher than for the years prior to 1934.

The estimates mentioned above are referred to as "proved" reserves. Reserves of this category include the amounts of petroleum recoverable by current methods of production from pools already proved by drilling. The estimate of January 1, 1939, by the American Petroleum Institute is accompanied by the explanatory statement that the estimate "covers all grades of crude oil and distillate known to be recoverable under existing economic and operations conditions." The different estimates of proved reserves do not include the as yet unknown amounts of petroleum that will be discovered in the future in new fields or in deeper zones or extensions of the present producing fields. The proved reserves in the ground, like the stocks of petroleum held in tank farms, at the refineries, and elsewhere, are constantly changing in quantity. They are depleted by the output of producing wells and increased by the discovery of new fields and deeper pools.

Mr. Cole. Doctor, are you going to read much more of this statement?

Mr. Miser. I just have one page.

Mr. Cole. There is quite a lot to it, and we are going to print the entire statement.

Mr. Miser. I have just one page.

Mr. Cole. All right, sir.

Mr. Miser. Or I will dispense with that, if you wish.

Mr. Mapes. I would like to ask a few more questions.

These estimates which you gave as related to the proved reserves are very interesting.

However, as I said this morning, it seems to me the important questions, as far as this legislation is concerned, are what are the wasteful methods of production and how those methods can be prevented. In that connection I would like to ask you this question: Suppose this legislation should be enacted into law and you were appointed Petroleum Administrator; what orders or regulations would you issue to prevent waste in the production of oil?

Mr. MISER. Congressman, I am a geologist and not a petroleum engineer. If I were appointed and placed in charge of this new set-up that is proposed by the Government—a thing I cannot imagine—I would employ other geologists and many petroleum engineers.

In the first place, it seems to me that a careful study would have to be made. It would take time; the sooner the better. A careful study would have to be made of geological conditions and production practices, the occurrence of oil and the gas in the ground. I think that would be a preliminary step toward determining how much oil is there and the determination of the reserves with reference to production. That would require considerable time and a large force of men.

Mr. MAPES. There is one provision in this bill that says that it shall be prima facie evidence of avoidable waste if a person produces oil one year after this law goes into effect unless he does so in accordance with the rules and regulations of the Petroleum Administrator.

Do you think that the Administrator would be able to survey all of the fields and make regulations in regard to production within a year?

Mr. MISER. If we get first-hand information on all oil fields of the United States within a year, it would take many times more geologists and engineers than we have available in the Government service in Washington and elsewhere in the country. That would be a tremendous undertaking. Most of the information that we have on the oil fields—the geology and the engineering practices—is based on the work of company geologists.

You see, there are possibly between 2,500 and 3,000 geologists who spend all their time on those matters.

Mr. MAPES. As I understand from you, you are not sufficiently familiar with the production of oil to tell the committee in a specific way what the waste in the production of it is?

Mr. MISER. I am in no position to speak on that subject.

Mr. MAPES. On page 12 of the bill, section 10 seems to contemplate the putting up of a laboratory to conduct experimentation, investigation, or demonstration relating to the application of engineering, chemistry, or economics to the location, drilling, and completion of oil and gas wells in oil fields, the reserves of crude oil and associated natural gas, including comparative studies of domestic and foreign reserves, the uses of oil, the field uses of natural gas, and the production, the refining, storage, transmission, and distribution of oil and its products and the liquid products of natural gas, as the Secretary shall direct or approve.

Mr. MISER. I beg your pardon; I did not catch that last question.

Mr. MAPES. As the Secretary shall direct or approve. That contemplates a pretty broad field, it seems to me.

Mr. MISER. It would, indeed.

Mr. MAPES. And an investigation in all branches of the industry. Can you tell us to what extent the industry itself is making investigations of that kind?

Mr. MISER. The industry is all the time devising new methods for the discovery of more oil. They are devising new ways of producing more oil more efficiently. Geologists nowadays do not spend their time working out the surface geology, as they once did; they spend much of their time with the producing department.

Mr. MAPES. Were you consulted in the drafting of this bill?

Mr. MISER. No, sir.

Mr. MAPES. Has there been any discussion in the Department as to whether it was contemplated that the Commissioner should carry out the provisions of that section quite extensively, or is it just a blanket section put in there for emergency purposes?

Mr. MISER. I have not had the opportunity to discuss this bill with Mr. Hudson or the other people who drafted it.

Mr. MAPES. I recall that 5 years ago the committee attended or visited some place out in Oklahoma where they have a laboratory of some kind.

Mr. COLE. Bartlesville, Okla.

Mr. MAPES. Bartlesville, Okla., Mr. Miser.

Mr. MISER. The Bureau of Mines has made studies there.

Mr. MAPES. To what extent is that doing what you contemplate by this section?

Mr. MISER. I believe, Congressman, you will need to ask some representative of the Bureau of Mines about that feature.

Mr. MAPES. I notice this language includes distribution of oil and its products. I think either you or some other witness this morning said it was not contemplated to control the distribution, the retail output by this bill?

Mr. MISER. I have no knowledge along that line. My only knowledge of the bill is from my reading of it.

Mr. COLE. Doctor, this is the statement you wanted to leave with the reporter.

Mr. MISER. Yes, sir.

Mr. COLE. That will be filed with the hearing for printing at this point.

(The report is in full as follows:)

## OUTSTANDING FEATURES OF OIL-FIELD DEVELOPMENT AND PETROLEUM GEOLOGY IN THE UNITED STATES, 1934-38

(By the Geological Survey, United States Department of the Interior[1])

The petroleum industry in the United States, which was born in 1859 with the discovery of oil in the Drake well in Pennsylvania, has reached this year 1939 its eightieth anniversary. During the last 80 years the industry has grown steadily in magnitude and service, it has produced altogether 21,000,000,000 barrels of oil from 22 States, it has met fully the power demands of our motor vehicles, our Navy, and our airplanes. In the future the industry is depended upon to continue its contribution to human welfare and progress, to continue to supply an important part of our power requirements, to continue its service in the maintenance of our national security.

The 5-year period of 1934–38 covered by the present report is thus a small portion of the life span of the petroleum industry in the United States; but, from comparison with like periods, not only is the production of the last 5 years the greatest, but the known reserves of petroleum have reached the highest figure in the history of the industry. This report describes briefly the oil-field developments, oil production, reserves, geologic features of productive areas, and oil possibilities of many areas that were being actively explored during the 5-year period. It supplements sections 6, 8, and 9 of the Geological Survey's report on "Geology and occurrence of petroleum in the United States," which was prepared in 1934 for the subcommittee of the Committee on Interstate and Foreign Commerce of the House of Representatives, Seventy-third Congress.

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[1] This report has been written by H. D. Miser with the collaboration of Paul Averitt, N. W. Bass, W. H. Bradley, C. H. Dane, A. M. Farrell, T. A. Hendricks, C. B. Hunt, P. B. King, W. G. Pierce, O. C. Postley, R. W. Richards, G. B. Richardson, and P. D. Trask.

That report, which was published in part 2 of the hearings of the committee on House Resolution 441, discusses many features of the oil industry in the United States, as may be noted from the following titles of the sections under which the material was there presented: (1) Early Discoveries and Uses of Petroleum; (2) Oil in the United States Before 1800; (3) Salt Industry (1800–1850) Prepares Way for Oil Production; (4) Oil from Coals and Shales for Light and Lubrication, 1850–59; (5) The Drake Well, 1859; (6) Some Outstanding Features of Oil Field Development in United States, 1859–1934; (7) The Origin of Petroleum; (8) Petroleum Geology Summarized by States; (9) Estimates of Petroleum Reserves; (10) Public and Indian Petroleum Lands.

## PRODUCTION OF PETROLEUM

The production of petroleum in the United States has mounted rapidly, especially during the twentieth century, when the growth of the petroleum industry has been related primarily to the expansion of the motor-fuel demand. The great volume of the present domestic production is strikingly illustrated by the fact that the total output of petroleum during the 5-year period, 1934–38, was 5.5 times greater than the total output—1,000,000,000 barrels—from 1859–1900. The present year, 1939, will probably witness the production of the twenty-second billionth barrel of oil. Twenty-two States have supplied the total output, amounting to 21,187,141,000 barrels through 1938. Texas ranks first among the States, having produced 5,602,834,000 barrels, a quarter of the total output of oil; California ranks second, with an output of 5,121,843,000 barrels, 24 percent; and Oklahoma is third, being credited with 4, 489,934,000 barrels, 21 percent. The total production of each of these 3 States is greater than that of the Union of Soviet Socialist Republics—3,989,784,907 barrels through 1938—which ranks next to the United States in cumulative production of petroleum.

Of the world's output of oil in 1938 (1,978,340,000 barrels), 61 percent (1,213,254,000 barrels), came from the United States. A similar proportion—57 percent—of the world's consumption of petroleum products and related fuels in 1938 was consumed in the United States.

Table 1 shows, by States, the production of petroleum in the United States for the years 1934–38, and the total production from 1859–1938. During the period 1934–37 the annual output of crude oil in the United States increased from 908,065,000 barrels to 1,279,160,000 barrels, but in 1938, coincident with the general change in economic conditions, the production decreased to 1,213,254,000 barrels, a decline of about 66,000,000 barrels. In 1934 the combined output of Texas, California, and Oklahoma amounted to 81.1 percent of the output of the United States for the year, but in 1938 this ratio had declined to 74.2 percent.

TABLE 1.—*Petroleum produced in the United States, 1934–38 and 1859–1938, by States*[1]

[Thousands of barrels of 42 gallons]

| | 1934 | 1935 | 1936 | 1937 | 1938[2] | Total 1859–1938[2] |
|---|---|---|---|---|---|---|
| Arkansas | 11, 182 | 11, 008 | 10, 469 | 11, 764 | 18, 077 | 459, 301 |
| California | 174, 305 | 207, 832 | 214, 773 | 238, 521 | 249, 749 | 5, 121, 843 |
| Colorado | 1, 139 | 1, 560 | 1, 650 | 1, 605 | 1, 412 | 36, 866 |
| Illinois | 4, 479 | 4, 322 | 4, 475 | 7, 499 | 23, 929 | 456, 967 |
| Indiana | 838 | 777 | 822 | 844 | 969 | 124, 395 |
| Kansas | 46, 482 | 54, 843 | 58, 317 | 70, 761 | 59, 587 | 993, 614 |
| Kentucky | 4, 860 | 5, 258 | 5. 633 | 5, 484 | 5, 821 | 156. 352 |
| Louisiana | 32, 869 | 50. 330 | 80, 491 | 90, 924 | 94, 812 | 862, 363 |
| Michigan | 10, 603 | 15, 776 | 11, 928 | 16, 628 | 19, 211 | 102, 357 |
| Montana | 3, 603 | 4, 603 | 5, 868 | 5. 805 | 4, 907 | 70, 765 |
| New Mexico | 16, 864 | 20, 483 | 27, 223 | 38, 854 | 35, 759 | 197. 993 |
| New York | 3, 804 | 4. 236 | 4, 663 | 5, 478 | 5. 045 | 108, 680 |
| Ohio | 4, 234 | 4, 082 | 3, 847 | 3, 559 | 3, 298 | 582. 062 |
| Oklahoma | 180, 107 | 185, 288 | 206, 555 | 228, 839 | 174. 882 | 4, 489. 934 |
| Pennsylvania | 14, 478 | 15, 810 | 17, 070 | 19, 189 | 17, 426 | 962, 333 |
| Texas | 381, 516 | 392, 666 | 427, 411 | 510, 318 | 475, 614 | 5, 602, 834 |
| West Virginia | 4, 095 | 3, 902 | 3, 847 | 3, 845 | 3, 684 | 403, 746 |
| Wyoming | 12, 556 | 13, 755 | 14, 582 | 19, 166 | 19, 004 | 453, 795 |
| Other States (Utah, Tennessee, Missouri, Mississippi) | 51 | 65 | 63 | 77 | 68 | 941 |
| Total United States | 908, 065 | 996, 596 | 1, 099, 687 | 1, 279, 160 | 1, 213, 254 | 21, 187, 141 |

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[1] White, A. G., Hopkins, G. R., and Breakey, H. A., Crude Petroleum and Petroleum Products (preprint): Minerals Yearbook 1939, p. 13, Bureau of Mines, 1939.

[2] Subject to revision

Changes in rank of some of the individual States during the 5-year period 1934–38 were as follows: From 1935 to 1938 Texas, California, and Oklahoma led the producing States in the order here named, but in 1934 Oklahoma ranked second and California third. In 1934–35 Kansas stood fourth, but in 1936–38 Kansas occupied fifth place, being displaced by Louisiana. Other notable changes were the rise of Michigan from tenth place in 1934 to eighth in 1938, and of Illinois from fourteenth place in 1936 to seventh in 1938.

About 40 percent of the total crude petroleum produced in the United States in 1934–38 was derived from the 15 fields that produced more than 50,000,000 barrels each during the 5-year period (see table 2); 2 of these fields, the Fitts and the Rodessa, are new, 6 of the fields are in Texas, 1 extending into Louisiana and Arkansas, 6 are in California, 2 are in Oklahoma, and 1 embraces adjoining parts of Pennsylvania and New York. The Wilmington field, in California, produced less than 50,000,000 barrels through 1938 and is therefore not included in the table. It was not discovered until 1936, but in 1938 it was the third largest producing field in the country.

TABLE 2.—*Annual production of crude petroleum in the 15 fields that produced more than 50,000,000 barrels each in the period 1934–38* [1]

[Thousands of barrels]

| Field and State | Year of first recorded production [2] | 1934 | 1935 | 1936 | 1937 | 1938 | Total 1934–38 | Total since discovery [3] |
|---|---|---|---|---|---|---|---|---|
| 1. East Texas,[3] Texas | 1930 | 181,500 | 176,900 | 167,500 | 170,700 | 152,100 | 848,700 | 1,285,000 |
| 2. Oklahoma City, Oklahoma | 1929 | 60,800 | 53,400 | 51,200 | 54,800 | 38,800 | 259,000 | 450,000 |
| 3. Kettleman Hills, California | 1928 | 21,400 | 27,600 | 29,300 | 29,100 | 25,600 | 133,000 | 202,000 |
| 4. Long Beach, California | 1921 | 23,000 | 26,600 | 25,000 | 21,900 | 20,700 | 117,200 | 621,000 |
| 5. Midway-Sunset, California | 1900 | 19,700 | 20,200 | 21,500 | 26,500 | 22,900 | 110,800 | 858,000 |
| 6. Bradford-Allegany, Pennsylvania-New York | [4] 1871 | 13,800 | 16,400 | 16,400 | 20,400 | 18,500 | 85,500 | 403,000 |
| 7. Rhodessa, Arkansas-Louisiana-Texas | 1935 | -------- | 1,400 | 22,100 | 31,800 | 27,500 | 82,800 | 82,800 |
| 8. Santa Fe Springs, California | 1921 | 14,700 | 16,200 | 16,500 | 15,700 | 12,600 | 75,700 | 447,000 |
| 9. Fitts, Oklahoma | 1934 | 300 | 6,900 | 19,900 | 31,000 | 16,700 | 74,800 | 74,800 |
| 10. Conroe, Texas | 1931 | 17,100 | 15,300 | 14,900 | 15,200 | 11,600 | 74,100 | 98,000 |
| 11. Huntington Beach, California | 1920 | 15,100 | 15,100 | 13,200 | 13,300 | 11,900 | 68,600 | 271,000 |
| 12. Yates,[3] Texas | 1926 | 16,000 | 15,900 | 13,400 | 11,400 | 7,400 | 64,100 | 247,000 |
| 13. Ventura Avenue, California | [5] 1926 | 9,900 | 11,000 | 12,600 | 12,700 | 12,900 | 59,100 | [2] 189,200 |
| 14. Pampa, Texas | 1927 | 12,300 | 11,200 | 10,900 | 13,400 | 10,900 | 58,700 | 147,000 |
| 15. Van,[3] Texas | 1929 | 14,600 | 14,100 | 12,500 | 11,300 | 5,600 | 58,100 | 115,000 |
| Total of the 15 fields, 1934–38 | -------- | -------- | -------- | -------- | -------- | -------- | 2,170,200 | -------- |
| Total of the United States, 1934–38 | -------- | -------- | -------- | -------- | -------- | -------- | 5,496,762 | -------- |

[1] From Oil and Gas Journal, Jan. 26, 1939, p. 78, except as noted.

[2] Petroleum Facts and Figures (except as noted), fifth and sixth editions, American Petroleum Institute.

[3] Bureau of Mines, except as noted.

[4] Pennsylvania Topographic and Geologic Survey Bulletin 116.

[5] Year discovered.

## IMPORTS AND EXPORTS

Despite the large production and consumption of petroleum and its refined products by the United States during the 5-year period, the imports and exports of petroleum and its refined products are relatively very small, though the exports have increased somewhat since 1933. (See table 3.)

Imports of crude petroleum consist mainly of heavy crude oil from Venezuela and Mexico, and exports consist principally of light crude oil produced in the midcontinent area and in California. In 1938 the exports were three times the imports and accounted for about 6½ percent of the quantity of crude petroleum produced in the United States. The exports of refined products in 1938 were four times the imports and were equal in volume to about 10 percent of the domestic production in that year.

TABLE 3.—*Imports and exports of petroleum and refined products*

[Thousands of barrels of 42 gallons]

| | 1934 | 1935 | 1936 | 1937 | 1938 |
|---|---|---|---|---|---|
| Imports. crude petroleum [1] | 35, 558 | 32, 239 | 32, 327 | 27, 484 | 26, 412 |
| Imports. refined products [2] | 14, 936 | 20, 396 | 24, 777 | 29, 673 | 27, 736 |
| Total | 50, 494 | 52, 635 | 57, 104 | 57, 157 | 54, 148 |
| Exports, crude petroleum [2] | 41, 127 | 51, 430 | 50, 313 | 67, 234 | 77, 273 |
| Exports, refined products [2] | 73, 380 | 77, 557 | 81, 681 | 105, 600 | 116, 633 |
| Total | 114, 507 | 128, 987 | 131, 994 | 172, 834 | 193, 906 |

[1] Bureau of Mines.
[2] Bureau of Foreign and Domestic Commerce.

## RESERVES

Although the United States produces and consumes three-fifth of the world's oil, its known reserves are about equal to those of the rest of the world. The reserves in the United States at the beginning of 1939, according to the different estimates, ranged from 14 to 17.5 billion barrels (see fig. 1 and pp. 11–14), whereas the reserves in foreign countries amounted to 17.9 billion barrels. (See table 4.)

TABLE 4.—*Estimated petroleum reserves of foreign countries January 1, 1939* [1]

[Millions of barrels of 42 gallons]

| | | | |
|---|---|---|---|
| Russia | 5, 000 | Colombia | 400 |
| Iran | 3, 500 | Argentina | 200 |
| Venezuela | 2, 500 | Peru | 200 |
| Iraq | 2, 500 | Trinidad | 150 |
| Dutch East Indies | 1, 600 | Others | 550 |
| Rumania | 700 | | |
| Mexico | 600 | Total | 17, 900 |

The known reserves of petroleum in the United States at the beginning of the 5-year period 1934–38 were placed at 13.3 billion barrels by H. B. Soyster, of the Geological Survey; and at the end of the period, January 1, 1939, they were placed at 17.3 billion barrels by the American Petroleum Institute. (See table 5.) On the basis of these two estimates the known reserves of petroleum increased 4 billion barrels in the 5 years since January 1, 1934, in spite of the production of 5.5 billion barrels in that period.

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[1] Garfias, V. R., and Whetsel, R. V., Estimate of World Oil Reserves: American Institute of Mining and Metallurgical Engineers, transcript, vol. 132, p. 609, 1939.

TABLE 5.—*Estimates of proved reserves of petroleum for years 1934–35, 1937–39*

[Thousands of barrels of 42 gallons. Other estimates are shown in figure 1]

| State | 1934 (Jan. 1): H. B. Soyster in U. S. Geologic Survey, Geology and Occurrence of Petroleum in United States: Petroleum investigation, House of Representatives, 73d Cong.; hearings on H. Res. 441, pt. 2, pp. 1071–1081, 1934 | 1935 (Jan. 1): Revised estimate American Petroleum Institute Committee on Petroleum Reserves, American Petroleum Institute Quarterly, vol. 7, No. 2, p. 5, April 1937 | 1937 (Jan. 1): Revised estimate American Petroleum Institute Committee on Petroleum Reserves, American Petroleum Institute Quarterly, vol. 8, No. 2, pp. 12–13, April 1938 | 1938 (Jan. 1): Revised estimate American Petroleum Institute Committee on Petroleum Reserves, American Petroleum Institute Quarterly, vol. 9, No. 2, pp. 7–8, April 1939 | 1939 (Jan. 1): Subject to revision. American Petroleum Institute Committee on Petroleum Reserves, American Petroleum Institute Quarterly, vol. 9, No. 2, pp. 7–8, April 1939 |
|---|---|---|---|---|---|
| Arkansas | 29, 500 | 103, 000 | 87, 493 | 171, 123 | 188, 246 |
| California | 5, 422, 500 | 3, 261, 000 | 3, 250, 726 | 3, 303, 512 | 3. 188, 763 |
| Colorado | 8, 500 | 16. 000 | 18, 622 | 19, 125 | 17, 713 |
| Illinois | 34, 000 | 37, 000 | 28, 210 | 58, 712 | 242, 847 |
| Indiana | 5, 000 | 5, 000 | 3, 441 | 6, 800 | 6, 031 |
| Kansas | 194, 000 | 390, 000 | 590, 000 | 607, 017 | 613, 230 |
| Kentucky | 30, 000 | 50, 000 | 38, 846 | 38, 366 | 37, 545 |
| Louisiana | 136, 000 | 513, 000 | 656, 844 | 1, 049, 198 | 1. 040, 256 |
| Michigan | 17, 000 | 64, 000 | 62, 614 | 45, 730 | 42, 749 |
| Montana | 57, 000 | 102, 000 | 115, 210 | 109, 378 | 104, 471 |
| New Mexico | 92, 500 | 451, 000 | 581, 025 | 738, 611 | 703, 252 |
| New York | 45, 000 | 75, 000 | 66, 000 | 45, 535 | 40, 490 |
| Ohio | 34, 000 | 40, 000 | 32, 000 | 29, 656 | 26, 358 |
| Oklahoma | 844, 500 | 1, 235. 000 | 1, 383, 464 | 1, 310, 652 | 1, 162. 370 |
| Pennsylvania | 252, 500 | 340, 000 | 307, 000 | 217, 886 | 200, 460 |
| Texas | 5, 884, 000 | 6, 643. 000 | 8, 343, 114 | 9, 691, 449 | 9, 447, 764 |
| West Virginia | 27, 500 | 40. 000 | 31, 976 | 28, 152 | 24, 468 |
| Wyoming | 245, 000 | 267, 000 | 259, 605 | 279, 937 | 261, 133 |
| Others | 1, 500 | ------------ | ------------ | ------------ | ------------ |
| Total | 13, 360, 000 | 13, 632, 000 | 15, 856, 190 | 17, 750, 839 | 17, 348. 146 |

About three-fourths of this increase of reserves has occurred in Texas, but other States with notable increases include Arkansas, Illinois, Kansas, Louisiana, and New Mexico. The several States whose reserves exceed 3 percent of the country's total, as given by the American Petroleum Institute for January 1, 1939, are:

|  | *Percent* |  | *Percent* |
|---|---|---|---|
| Texas | 54. 5 | Louisiana | 6 |
| California | 18. 4 | New Mexico | 4 |
| Oklahoma | 6. 7 | Kansas | 3. 5 |

Estimates are given in table 5 for each State for January 1, 1934, 1935, 1937, 1938, and 1939. Other estimates for the 5-year period 1934–38 and also for previous years are shown in figure 1 and and on pages 12–14.

*Estimates of petroleum reserves indicated by corresponding numbers of figure 1*

1. 5,000,000,000 barrels. Estimate by joint committee representing the American Association of Petroleum Geologists and the Geological Survey in The Oil Supply of the United States: Am. Assoc. Petroleum Geologists Bull., vol. 6, No. 1, pp. 42–46, 1922.
2. 5,321,427,000 barrels, 1925. A report to the board of directors of the American Petroleum Institute by a committee of 11 members of the board in American Petroleum Supply and Demand. 1925.
3. 4,500,000,000 barrels, September 6, 1926. Report of the Federal Oil Conservation Board to the President of the United States, pt. 1, p. 8, 1926.
4. 7,704,000,000 barrels. H. J. Struth, Oil Weekly, vol. 65, No. 5, pp. 16–18, Apr. 18, 1932.
5. 9,071,000,000 barrels. H. J. Struth, idem.
6. 9,199,000,000 barrels. H. J. Struth, idem.
7. 10,000,000,000 barrels. W. E. Pratt, Industry Must Drill 20,000 wells yearly: Oil and Gas Jour., vol. 30, No. 9, pp. 19, 102–103. July 16. 1931.
8. 10,578,000,000 barrels. H. J. Struth, op. cit., pp. 16–18.
9. 10,000,000,000 barrels, October 1932. Report V of the Federal Oil Conservation Board to the President of the United States, pp. 7, 41, 1932.
10. 12,000,000,000 barrels. V. R. Garfias, An Estimate of the World's Proven Oil Reserves: Am. Inst. Min. Met. Eng. Trans., vol. 103, pp. 352–354, 1933.

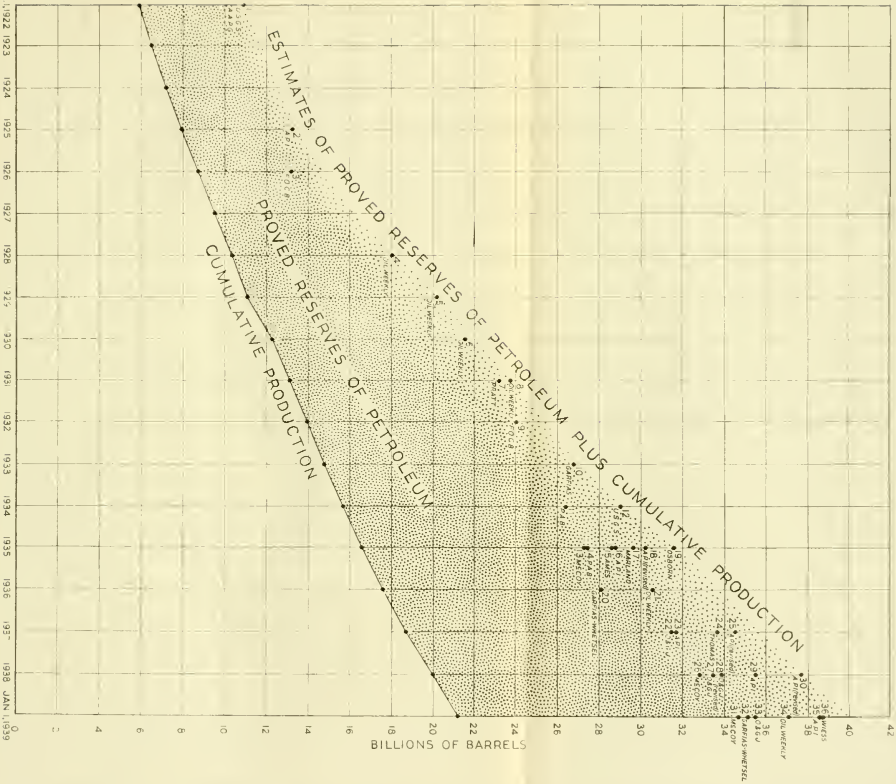

FIGURE 1. Production and proved reserves of petroleum, 1922–38. Numbers correspond to those on pages 12–14; cumulative production as of January 1 of each year; estimates of proved reserves as of same date, except as noted on pages 12–14.

11. 10,638,000,000 barrels. Petroleum Administrative Board, Report on the Cost of Producing Petroleum, p. 133, 1936 [issued December 1935].
12. 13,360,000,000 barrels. H. B. Soyster, Estimates of Petroleum Reserves, in Geology and Occurrence of Petroleum in the United States, by the Geological Survey: Petroleum Investigation; hearings before subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73d Cong., on H. Res. 441, pt. 2, pp. 1071–1081, 1934.
13. 10,700,000,000 barrels. Statement of A. W. McCoy: Petroleum Investigation; hearings before subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73d Cong., on H. Res. 441, pt. 3, pp. 1454–1458, 1934.
14. 10,763,000,000 barrels. Petroleum Administrative Board, Report on the Cost of Producing Petroleum, p. 133, 1936 [issued December 1935].
15. 12,000,000,000 barrels, probably as of August 1934. Statement of C. B. Ames: Petroleum Investigation; hearings before subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73d Cong., on H. Res. 441, pt. 1, p. 359, 1934.
16. 12,177,000,000 barrels. Estimate by a special committee of the American Petroleum Institute, in Petroleum Production and Supply: Am. Assoc. Petroleum Geologists Bull., vol. 20, No. 1, pp. 1–14, January 1936.
17. 13,000,000,000 barrels, Nov. 12, 1934. Statement of E. W. Marland: Petroleum Investigation; hearings before subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73d Cong., on H. Res. 441, pt. 3, pp. 1439–1445, 1934.
18. 13,632,000,000 barrels. Estimate by American Petroleum Institute Committee on Petroleum Reserves in Nation's Proven Oil Reserves Placed at 13,000,000,000 Barrels: Am. Petroleum Inst. Quart., vol. 7, No. 2, p. 5, April 1937.
19. 15,000,000,000 barrels. Statement of Campbell Osborn: Petroleum Investigation; hearings before subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73d Cong., on H. Res. 441, pt. 3, pp. 1458–1463, 1934.
20. 10,575,000,000 barrels. V. R. Garfias and R. V. Whetsel, Proven Oil Reserves: Am. Inst. Min. Met. Eng. Trans., vol. 118, pp. 211–214, 1936.
21. 12,992,000,000 barrels. W. L. Baker, Oil Weekly, vol. 80, No. 9, pp. 19–22, Feb. 10, 1936.
22. 12,904,946,000 barrels. L. G. E. Bignell, Oil and Gas Jour., vol. 36, No. 37, pp. 38–39, Jan. 27, 1938.
23. 13,063,000,000 barrels. Estimate by American Petroleum Institute Committee on Petroleum Reserves, in Nation's Proven Oil Reserves Placed at 13,000,000,000 Barrels: Am. Petroleum Inst. Quart., vol. 7, No. 2, p. 5, April 1937.
24. 15,000,000,000 barrels. J. E. Thomas, Proved Oil Reserves in United States of America: Am. Assoc. Petroleum Geologists Bull., vol. 21, No. 8, pp. 1088–1091, 1937.
25. 15,856,190,000 barrels. Institute Committee Estimates, Nation's Proven Petroleum Reserves at New High: Am. Petroleum Inst. Quart., vol. 8, No. 2, pp. 12–13, April 1938.
26. 12,909,000,000 barrels. Estimate by A. W. McCoy, Oil Weekly, vol. 88, No. 8, pp. 10–11, Jan. 31, 1938.
27. 13,489,457,000 barrels. L. G. E. Bignell, Oil and Gas Jour., vol. 36, No. 37, pp. 38–39, Jan. 27, 1938.
28. 13,975,816,944 barrels. L. G. E. Bignell, Oil and Gas Jour., vol. 37, No. 35, p. 20, Jan. 12, 1939.
29. 15,507,268,000 barrels. Institute Committee Estimates Nation's Proven Petroleum Reserves at New High: Am. Petroleum Inst. Quart., vol. 8, No. 2, pp. 12–13, April 1938.
30. 17,750,839,000 barrels. Estimate by American Petroleum Institute Committee on Petroleum Reserves: Am. Petroleum Inst. Quart., vol. 9, No. 2, pp. 7–8, April 1939.
31. 13,584,000,000 barrels, Sept. 1, 1938. A. W. McCoy, Estimate of Petroleum Reserves, United States, Ponca City, Okla., September 1938.
32. 14,000,000,000 barrels. V. R. Garfias and R. V. Whetsel, Estimate of World Oil Reserves: Am. Inst. Min. Met. Eng. Trans., vol. 132, pp. 608–611, 1939.
33. 14,351,520,297 barrels. L. G. E. Bignell, Oil and Gas Jour., vol. 37, No. 35, pp. 20–23, Jan. 12, 1939.
34. 15,890,840,000 barrels. W. L. Baker, Oil Weekly, vol. 92, No. 7, pp. 44–46, Jan. 30, 1939.
35. 17,348,146,000 barrels. Estimate by American Petroleum Institute Committee on Petroleum Reserves: Am. Petroleum Inst. Quart., vol. 9, No. 2, pp. 7–8, April 1939.
36. 17,505,000,000 barrels. H. C. Wiess, Some Current Problems in Oil Conservation: Oil and Gas Jour., vol. 37, No. 41, pp. 46–170, Feb. 23, 1939.

An examination of the graphic representation of the Nation's known reserves, shown on figure 1, reveals the fact that the increase in reserves for the 5-year period 1934–38 has about equaled that for many preceding years. The estimate of 5,000,000,000 barrels of oil "in sight" in 1922 and Soyster's estimate of 13.3 billion barrels for January 1, 1934, indicate an increase of 8.3 billion barrels for this 12-year period, equal to an annual increase of about 0.7 billion barrels. On the other hand, the increase of 4,000,000,000 barrels in reserves for the 5-year period 1934–38, indicated by the estimate of 13.3 billion barrels by Soyster for January 1, 1934, and the estimate of 17.3 billion barrels by the American Petroleum Institute for January 1, 1939, is equal to an annual increase of 0.8 billion barrels.

The estimates mentioned above are referred to as "proved" reserves. Reserves of this category include the amounts of petroleum recoverable by current methods of production from pools already proved by drilling. The estimate of January 1, 1939, by the American Petroleum Institute is accompanied by the explanatory statement that the estimate "covers all grades of crude oil and distillate known to be recoverable under existing economic and operating conditions."[2] The different estimates of proved reserves do not include the as yet unknown amounts of petroleum that will be discovered in the future in new fields or in deeper zones or extensions of the present producing fields. The proved reserves in the ground, like the stocks of petroleum held in tank farms, at the refineries, and elsewhere, are constantly changing in quantity. They are depleted by the output of producing wells and increased by the discovery of new fields and deeper pools.

The survival of the petroleum industry, like that of most other mineral industries, depends on the continued discovery of new sources of supply. The extent to which new sources are discovered and made to produce depends upon the payment by the consumer of prices that will permit the industry to carry the heavy and increasing expense of new exploration and maintain profits.

Much oil remains to be discovered in new fields and in deeper pools, but the exact location of these fields and the quantity of petroleum they will yield will not be known in advance of drilling. Nevertheless, their number, whatever it may be, is definitely limited, and each newly found field leaves one less to be discovered.

The answer to the question When will the day of petroleum shortage in the United States be reached? lies not alone in the supply of oil remaining in the ground. It rests also with the geologist to continue to aid in the increasingly difficult problem of discovery, with the engineer to improve drilling technique and to increase recoveries, and with the chemist to continue improvements in refining practice. In part it rests on the price that the public can pay in the future for oil products, which in turn depends in part on increased efficiency in use. In a large measure it rests on conservation and efficiency in the discovery, development, and production of our future oil fields.

Undoubtedly there will be continued advances in science and technology affecting the discovery, recovery, refining, and utilization of petroleum. Thus far, such advances have enabled us to keep supplies ahead of needs, but they afford us no assurance that the same record can be maintained indefinitely.

In this connection it is of interest to call attention to some of the concrete accomplishments of recent years. The amount of gasoline recovered from a barrel of oil has more than trebled in the last 40 years—from about 5½ gallons in 1899 to about 18½ gallons in 1938. In the 5-year period from January 1, 1934, to January 1, 1939, the geologist and the petroleum engineer have aided the driller in the addition of 4,000,000,000 barrels to our petroleum reserves, despite the production of 5.5 billion barrels during that period. The petroleum engineer is meeting energetically the challenge to recover the 65 to 85 percent of oil remaining in the ground after a field no longer yields oil by the older methods of production. Each year witnesses the improvement and extension of recovery methods, such as acid treatment and repressuring by the introduction of gas, air, and water into the oil-bearing zones. The increased adoption and refinement of such methods in areas where geologic and other conditions permit their use will lead to the recovery in places of 50 percent or more of the total oil content of the producing zones.

Moreover, when a shortage of domestic crude petroleum arrives and there is a consequent rise in prices of petroleum products, substitutes will be utilized just as they are now used to some extent in certain countries that have little or no oil resources. Some of these substitutes are oil products from coal and oil shale, alcohol from farm products, and gases from wood. Our future resources of coal and oil shale have been so closely determined by geologic evidence and exploration that we know their approximate extent and quantity. According to Winchester,[3] who conducted investigations of the oil-shale deposits of the United States for the Geological Survey, they will yield 92,144,935 000 barrels of oil, if and when the price of oil permits. Should coal be called upon to supply the demands now met by oil and gas, the coal reserves of the United States would, according to independent estimates by Hendricks[4] and Fieldner,[5] last about 2,000 years. These two estimates are based on the assumption that the consumption of energy from mineral fuels will equal the maximum rate of consumption in the past (approximately 23,400 trillion British

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[2] American Petroleum Institute, press release, February 27, 1939.

[3] Winchester, D. E., the Oil Possibilities of the Oil Shales of the United States: Federal Oil Conservation Board Rept. II to the President of the United States, pp. 13–14, 1928.

[4] Hendricks, T. A., Coal Reserves in Energy Resources and National Policy, Report of the Energy Resources Committee to the National Resources Committee, p. 281, 1939.

[5] Fieldner, A. C., Fuels of Today and Tomorrow: American Society for Testing Materials Proceedings, vol. 37, pt. 1, 1937.

thermal units in 1929) and also on the assumption of a 30-percent loss of coal in mining. Concerning the cost of motor-fuel substitutes, Fieldner comments as follows:

"Reliable information on the cost of making gasoline from coal in British and German plants is not available, but it is believed that it is three or four times the present cost of producing gasoline from petroleum in the United States. These costs will be reduced by further research, but no other liquid motor fuel, whether it be from coal, oil shale, or vegetable matter, can hope to be as cheap as our present petroleum fuels."

### CURRENT METHODS EMPLOYED IN PETROLEUM GEOLOGY

In the solution of the geologic problems involved in the search for oil, new methods of technique and new trends in the application of geology are developed and adopted from time to time by the oil industry, and old methods and practices are frequently modified or abandoned. Some of the current methods and practices employed in petroleum geology are here briefly mentioned.

Surface geologic surveys to locate favorable areas for oil by the mapping of anticlines, domes, and other structural features reached their peak application between 1920 and 1925 and have thus occupied for many years a place of decreasing importance in the finding of new oil fields. This decline is attributable to the gradual decrease in the number of favorable drilling localities that can be recognized at the surface. Accordingly, from year to year, an increasing proportion of effort and funds is devoted to the study of subsurface geologic features that are not discernible from an examination of the exposed formations. Among such features are oil reservoirs of a type commonly known as stratigraphic traps. Such reservoirs may be due to variations in porosity, permeability, and lithology, to lensing, to shore-line phenomena, and to various lateral gradations. One-fourth to one-third of the past domestic production, according to Levorsen,[6] has been obtained from stratigraphic traps. Many oil pools in such reservoirs are of large size, and among them are the East Texas field in Texas, the Glenn pool in Oklahoma, and the Coalinga and Midway-Sunset pools in California. For this reason and also for the reason that past development has tested an increasing number of favorable structural features and has thereby gradually reduced the number remaining to be discovered, the search for stratigraphic traps has in recent years been intensified in many areas.

Because of this increasing importance of subsurface geology in comparison with surface geologic mapping in the discovery of oil, the current methods employed in petroleum geology, mentioned below, are used for the most part as tools for the acquisition of information in the solution of subsurface stratigraphic and structural problems.

Core drilling for the determination of geologic structure was introduced in the United States in 1919 and is still being employed in parts of the midcontinent region. Also, in this and other regions it is current practice to obtain especially the cores of oil sands and other important beds for a study of their character and fossil content. Small cores obtained with sample-taking bullets shot from a device patterned after the casing perforator began to be used in 1938 in conjunction with electrical logging, mentioned beyond. These small samples are taken at precisely located spots to check the properties of beds not adequately revealed by the electrical logs, to locate more precisely gas-oil and oil-water contacts, and to measure porosity and various other physical properties of the oil sands.

In recent years rapid routine methods for measuring the physical characteristics of sandstone cores have been developed. These characteristics include permeability, porosity, grain size, and fluid contents; and the results obtained from their measurement are utilized in the estimation of the oil and gas reserves in a pool.

The laboratory orientation of well cores by their magnetic polarity, developed in 1928, was much improved in 1935 and 1936 and provides a rapid and inexpensive method of determining the dip of core samples that have good bedding planes and a sufficient content of heavy minerals in which polarity has been induced by the earth's magnetic field.

The microscopic examination of well cuttings was begun on a large scale in 1917 and since that time it has reached a place of fundamental importance. To it the oil geologists now give about half of their effort. A special method for

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[6] Levorsen, A. I., Stratigraphic Versus Structural Accumulation: American Association of Petroleum Geologists Bull., vol. 20, No. 5, pp. 521–530. May 1936.

the study of well cuttings of limestones and dolomites that was introduced in 1924 by McQueen[7] consists of a microscopic examination of insoluble residues that are obtained by dissolving the cuttings in hydrochloric acid. This type of examination of well cuttings has been successfully utilized in a large part of the United States—from Ohio and Tennessee on the east to Kansas and New Mexico on the west—for the determination of underground stratigraphy and structure.

Micropaleontology, which has been an integral part of the oil business in the United States since 1924, is employed for determining the age and local and distant correlations of the rock strata.

Geophysical methods, magnetic, gravimetric, electrical, and seismic, are widely used in the United States by the oil industry as a means for locating and mapping buried structural features. The adoption of the seismograph followed the discovery of its applicability during the World War for locating long-range guns. In its use by the oil industry the shots from long-range guns are replaced by explosive charges in prospective oil localities. In 1924 oil companies discovered three salt domes in the Gulf coast region by geophysical methods, but since then more than 100 salt domes in the Gulf coast region and many other structural features from New York to California have been located by means of such methods and later established by drilling.

The period 1934–38 was especially active in the expansion of the use of geophysical instruments in the search for oil; and their application has been rewarded during each year of the 5-year period by the discovery of an increasing number of oil fields. The limitations and special adaptabilities of the several geophysical methods for the solution of geologic problems have become better understood, and a fuller understanding of the objectives sought has led to refinements of instrument construction and operational technique that are aimed at the accumulation of subsurface geologic data rather than merely the detection of physical anomalies in the earth's crust.

As an exploratory method the seismic reflection method is dominant over all others and has largely replaced the refraction seismic method. Refraction seismic surveys continue to be employed to some extent, especially for the solution of special problems, such as thickness of sedimentary cover, attitude of basement rocks, and detailed mapping of flanks of piercement-type salt domes by utilizing recorders lowered into existing wells. Recently refraction seismic surveys have been used to some extent in the examination of the under-water areas of the Gulf coast.

Of the exploratory methods involving the measurement of gravity, the pendulum method is the oldest and is of great importance in establishing the absolute value of gravity. Although of use in surveying some of the more pronounced local anomalies, it has never been widely used for exploration. The torsion balance has had its greatest application in the Gulf coast region, where it has been very successful in locating salt domes. Beginning in 1936 use of the modern gravity meter has increased greatly and has in part replaced that of the torsion balance.

Magnetic prospecting, based on the difference in magnetic properties of rocks due to dissemination of minerals of different magnetic susceptibilities, was curtailed during the period 1934–38. Refinements in the construction of magnetometers have been made, but in the opinion of many observers the magnetometer remains only a reconnaissance instrument.

The electrical logging of drill holes was developed in 1928, and its applications have become increasingly valuable from year to year. From the records or logs obtained by this method, the salt water, fresh water, oil content, and permeability of the rocks can be inferred. The value of electrical logging to the industry as a direct method in establishing oil-water contacts and the nature and thickness of all oil- and water-bearing zones is large. Also, the method affords possibilities for prediction of the recoverable oil in a field. The logs provide an easy and accurate means of distinguishing different formations. Their use permits short-distance correlation of formations within oil fields and, in conjunction with lithologic and paleontologic studies of cores and cuttings, permits also long-distance regional correlations. As a rapid precise tool for correlation the method provides a complete and relatively inexpensive picture of the relations of the beds underground in producing fields, including the lensing of beds, the distribution and throw of faults, and the presence of

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[7] McQueen, H. S., Insoluble Residues as a Guide in Stratigraphic Studies: Missouri Bureau of Geology and Mines, 56th Biennial Report, appendix I, 1931.

unconformities. Recently the use of electrical logs has revived shallow subsurface correlation in exploring for structural features. This has been undertaken by small-diameter holes about 1,000 feet deep drilled solely for the benefit of correlations obtainable from electrical diagrams, especially in regions where shallow lithologic and paleontologic marker beds are not available.

Methods involving the introduction of electrical fields into the earth and measuring their effects at the surface, geothermal methods involving the measurement of the rate of flow of heat through different formations, radioactive methods, and methods involving anomalies in reception of radio waves have been employed to a greater or less degree, in part experimentally, for some years in the exploration for structural and stratigraphic features in oil-bearing areas, but all are definitely of subordinate importance at the present time.

A method commonly known as soil analysis, whereby the areas of greatest concentrations of hydrocarbons in the soils are determined, is at present receiving consideration as a possible aid in the exploration for oil.

A development that is of great value not only in geologic mapping but also in other phases of the oil industry is that of airplane photography. Such photography was first utilized for military purposes during the World War and was employed about 1920 by oil geologists. As a result of the tremendous improvement of airplanes, cameras, and photographic methods during the last 5 years, mapping of this kind has become an indispensable tool of the petroleum industry. Aerial photographs serve a multitude of purposes. The oil geologists use the mosaics as a base on which to plot the geology; and the individual photographs from which the mosaic is made are studied stereoscopically to obtain a photographically exact model of the land surface. Many conditions bearing on the geology are more readily recognized in stereoscopic photographs than by actual field surveys. These include such features as changes in vegetation and soil, irregularities of stream courses, and minor topographic features. Photographic maps are also used for routing pipe lines so that necessary variations from direct routing to avoid hazards can be anticipated. They are useful for obtaining the considerable ground detail necessary for locating pipe-line stations, terminals, or other structures. They faithfully show landmarks, so that orderly handling of land leases is facilitated, and they help in the selection of routes for transporting materials into wildcat areas. Indeed, aerial photographs are useful to so many industries and governmental activities that about two-thirds of the area of the United States has been so photographed. Table 6 shows the approximate percentage of the area photographed in each of the 22 oil-producing States at the end of 1938.

TABLE 6.—*Approximate percentage of the area photographed aerially in each oil-producing State at the end of 1938*[1]

| | Percent | | Percent |
|---|---|---|---|
| Arkansas | 95 | Montana | 50 |
| California | 25 | New Mexico | 60 |
| Colorado | 95 | New York | 60 |
| Illinois | 100 | Ohio | 100 |
| Indiana | 100 | Oklahoma | 95 |
| Kansas | 100 | Pennsylvania | 100 |
| Kentucky | 90 | Tennessee | 100 |
| Louisiana | 100 | Texas | 80 |
| Michigan | 95 | Utah | 40 |
| Mississippi | 95 | West Virginia | 55 |
| Missouri | 100 | Wyoming | 15 |

[1] A small percentage of the area included herein has been flown by the Army Air Corps, and these photographis are not generally available.

## DEEP DRILLING

With continued improvements in drilling technique, wells in search of oil have been drilled to greater and greater depths and they have discovered oil pools at these greater depths in some areas. (See table 7.) Nevertheless, there is a depth limit beyond which oil will not be found. In many areas this limit is clearly marked by the floor or basement of crystalline rocks, but in other areas the oil-bearing rocks may be less clearly limited below by sedimentary rocks whose lithification or other features are such as to preclude their containing oil.

TABLE 7.—*Some statistics on deep drilling in 1934–38*[1]

| Year | Deepest drilled depth (feet) | Deepest producing depth (feet) | Wells completed more than 10,000 feet deep | Fields producing from depths greater than 10,000 feet |
|---|---|---|---|---|
| 1934 | 11,377 | 9,710 | 3 | ---------- |
| 1935 | 12,786 | 9,836 | 7 | ---------- |
| 1936 | 12,786 | 9,950 | 8 | ---------- |
| 1937 | 12,786 | 11,302 | 40 | 5 |
| 1938 | 15,004 | 13,266 | 142 | 10 |

[1] Compiled from Petroleum Facts and Figures, 1939, and the Oil Weekly, July 31, 1939.

Prior to 1931 not a single well in the United States extended to a depth of 10,000 feet. By the beginning of 1934 four wells between 10,000 and 11,000 feet in depth had been drilled, and in 1934 one well reached a depth of 11,377 feet. By the end of 1938 203 wells had been drilled below 10,000 feet, and 18 fields—10 in Louisiana, 6 in California, and 2 in Texas—were producing oil from depths between 10,000 and 13,266 feet. These new areas have added an estimated 460,000,000 barrels of oil to our national reserves.[7a]

The world's deepest well, completed in 1938 in the southern San Joaquin Valley, Calif., is 15,004 feet in depth. This well is nearly 9,000 feet deeper than the mine workings (slightly more than 6,150 feet) of the Quincy Mining Co., Hancock, Mich., and is about 6,500 feet deeper than the 8,530-foot workings of one of the Crown mines on the Rand. The producing zone of this deep California well lies at a depth of 13,092 to 13,175 feet, but a more recently completed well of the Fohs Oil Co. in Terrebonne Parish, La., is producing from a slightly greater depth; namely, 13,254 to 13,266 feet.

## CONDENSATE POOLS

A type of reservoir known as a condensate or distillate pool has been discovered with increased frequency as the wells in search of petroleum have reached progressively greater depths. In its order of January 18, 1939, the Railroad Commission of Texas states "that a condensate well is one in which the liquids obtained at the surface are in the gas phase in the reservoir and are formed by the decrease in pressure and temperature which occurs after such gas leaves the reservoir; that such condensate wells produce hydrocarbon liquids which are usually water-white in color and are not crude petroleum." Some reservoirs may be entirely filled with gas containing its water-white condensable products, but at other places the condensate-bearing gas occurs in the same reservoir with dark oil.

Condensate liquid production of this type was originally obtained in the Kettleman Hills (Calif.), Oklahoma City (Okla.), and Big Lake (Tex.) fields. A list of condensate pools published in October 1939 names 123 fields in Texas and Louisiana.[8] The production of condensate from 49 fields in south Texas during the first 6 months of 1939 was 1,112,588 barrels.[9]

The condensate reservoirs range in depth from 2,270 to 11,178 feet and the temperatures in them range from 145° to 235° F. The condensate fluid ranges in gravity from 31° to 70° (A. P. I.). Where no market is available for the great volumes of gas that are produced in order to recover the condensate economically, the fields have been shut in. In some fields, however, condensate is produced by maintaining the reservoir pressure, and after the extraction of the condensate the gas is recompressed and forced back into the reservoir. The maintenance of the reservoir pressure not only permits a more complete recovery of condensate but prevents precipitation of the condensate in the reservoir.

## OFFSHORE MARINE PRODUCTION

The geology of parts of the California coast and the Gulf coast of Louisiana and Texas long ago led geologists to infer the presence beneath the coastal

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[7a] Oil Weekly, vol. 24, no. 8, p. 64, July 31, 1939.

[8] Weber, George, Recycling Trend Expands With Bigger Gas Reserves: Oil and Gas Journal, vol. 38, No. 21, pp. 36–39, October 5, 1939.

[9] Post, E. S., South Texas Growing as a Distillate Producing Area: Oil Weekly, vol. 95, pp. 44–46, October 9, 1939.

waters of traps suitable for the accumulation of petroleum. Along the California coast the favorable structural features are anticlines that belong to groups or systems of similar anticlines that are exposed on shore and that there produce oil. Under the coastal waters of the Gulf of Mexico salt domes like those that produce oil along the shore are inferred not only from the regional geology but also from the presence of mounds on the sea floor comparable in shape and size to the hills on land above certain salt plugs.

By the end of 1933 several of the offshore anticlines along the California coast had been proved to be productive and the Elwood, Huntington Beach, Rincon, El Capitan, and Summerland fields rather fully developed. Oil is now also produced from submerged land in the Wilmington field. Two methods of exploiting the offshore folds were evolved. At Elwood, Santa Barbara County, the wells were drilled from piers built out from shore. During the period 1934–38 some of these piers were built out about 2,000 feet from shore and wells were drilled in water 41 feet deep. The principal new development, however, has been the use of directional drilling, so that seven wells can be drilled from one foundation unit. These wells range in slope from nearly vertical to 14° from the vertical. At Huntington Beach, in Orange County, an offshore anticline was drilled entirely by slanting wells from derrick locations on shore. The deeper parts of these wells slope 40° to 60° from the vertical. It has been reported that 86 slanted wells produced nearly 30,000,000 barrels of oil at Huntington Beach between 1933 and 1937. Originally these wells were flowing wells but now, despite their slant, they are being pumped.

Early in 1938 the first salt-dome oil field (Creole field) in the open water of the Gulf of Mexico was discovered about a mile off the shore of Cameron Parish, La., in 14 feet of water. Five more oil wells had been drilled on this dome by the first quarter of 1939, and the ultimate recovery of the field was estimated to be 2,000,000 barrels. The producing wells are about 5,000 feet deep. Also in 1938 wells on two other salt domes were drilled in the open waters of the Gulf. One is about a mile off the shore of Jefferson County, Tex., and the other is about 2½ miles southwest of Coon Point on Isle Dernieres, off the shore of Terrebonne Parish, La. Several wells have been drilled on each of these salt domes, but all are dry. Nevertheless, it is expected that further drilling will eventually develop both domes into oil fields.

In the open waters of the Gulf of Mexico two methods of drilling have been used—piling foundations and submersible barges. Because of the expense of piling foundations some drilling companies now plant to drill as many as nine slanting wells from one foundation unit. Submersible barges are connected in pairs by a superstructure which serves as the derrick foundation. The barges have the great advantage of mobility and economy.

The shallow water in the Gulf of Mexico should be a great aid to the development of submarine oil fields. Within the 3-mile limit depths greater than 25 to 30 feet are rare, and even out to 35 miles from the coast the water is rarely more than 60 feet deep and locally is only about 25 feet deep. Hurricanes endanger both drilling and completed wells, but suitable protective devices have been designed and should prove effective, particularly against wells blowing wild and consequent loss of the field.

It has been estimated[10] that the offshore anticlines along the California coast contains a reserve of 1,000,000,000 barrels of oil. The reserves of oil beneath the Gulf of Mexico have not been estimated but must be tremendous if salt-dome fields prove to be as numerous in the submerged offshore belt as they are along a similar adjacent belt on shore.

The legal question of the ownership of the oil and gas deposits underlying submerged lands extending seaward from the low-water mark is now receiving congressional study.

## OIL-FIELD DEVELOPMENT AND PETROLEUM GEOLOGY, 1934–38, SUMMARIZED BY STATES

Summaries are here given of the outstanding developments during the 5-year period in the exploration for oil in each of the 22 States that have produced oil. The summaries are grouped under eight headings—the Appalachian region, Michigan, Indiana, and Illinois, in the northeastern part of the United States; the Mid-Continent, Gulf coast, and Rocky Mountain regions; and California. These

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[10] Kemnitzer, W. J., Rebirth of Monopoly, p. 72, New York, 1938.

summaries constitute a supplement to section 8, "Petroleum geology summarized by States," in part 2 of the hearings before a subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, Seventy-third Congress, on House Resolution 441.

In the preparation of the summaries use has been made of all available information, including State and Government publications and the numerous technical and trade journals dealing with various phases of the petroleum industry. The statistical data on production, reserves, and drilling were taken from many different sources. Data from various reliable sources differ. Although not, therefore, rigorously comparable, the data selected for inclusion in the summaries are believed to show adequately general relations and trends for the period.

## APPALACHIAN REGION

(New York, Pennsylvania, Ohio, West Virginia, Kentucky, and Tennessee)

The output of Pennsylvania-grade crude oil in New York, Pennsylvania, West Virginia, and eastern Ohio increased during the years 1934–37. As reported by the Bureau of Mines, the output of Pennsylvania grade oil was 23,958,000 barrels in 1934 and 29,862,000 barrels in 1937. The increase was due to the expanding use of secondary recovery methods, chiefly water flooding in the Bradford-Allegany district of Pennsylvania and New York. Preliminary figures for 1938 show an output of 27,316,000 barrels, a decline of more than 2,500,000 barrels, owing to decreased demand consequent upon the business depression, price reduction, and proration.

The production of oil in Kentucky increased from 4,860,000 barrels in 1934 to 5,821,000 barrels in 1938. Most of the increase came from the western part of the State, where 17 new fields were discovered during the period. Production in eastern Kentucky for 1938 was more than 2,000,000 barrels. Tennessee produced only 133,000 barrels of oil during the period.

No new oil fields of outstanding importance were discovered in New York, Pennsylvania, West Virginia, or Ohio during the 5-year period, 1934–38. Drilling for oil was confined chiefly to the old fields and to routine work, fulfilling lease requirements, sinking offset wells, and drilling in water-drive areas. Numerous wildcat wells drilled outside of the oil fields in search of gas in the deep-lying Oriskany sandstone resulted in the discovery of many gas-producing areas, but oil in commercial quantity in the Oriskany sandstone was found in only one well, in Kanawha County, southeast of Charleston, W. Va., in the fall of 1934.

Estimates of reserves of oil recoverable by current methods in known fields, prepared by the American Petroleum Institute, show a total of 291,776,000 barrels January 1, 1939, for New York, Pennsylvania, West Virginia, and Ohio.

Considering that New York, Pennsylvania, West Virginia, and Ohio have been rather intensively drilled for a period of 80 years, it seems unlikely that many large oil fields remain to be discovered in these States. However, because of the "spotted" occurrence of oil in this region, in lenticular sands of variable porosity and permeability, it is to be expected that small fields will continue to be found in areas that have been missed by previous drilling. In the search for new fields of the stratigraphic type, it will be helpful to study subsurface conditions by examination of core samples of the sands and by study of electrical logs, seeking porous streaks in the rocks that would trap the oil where they grade laterally into impermeable beds. Structural traps for oil also will continue to be sought. The structure of the surface rocks is well known except in the areas covered by glacial deposits in southern New York, northwestern Pennsylvania, and northeastern Ohio. The structure of the deep-lying rocks, because of the convergence of the beds, may be considerably different from the structure of the surface rocks, so that increasing dependence is being placed on geophysical work, in particular reflection—seismograph methods.

### NEW YORK

Most of the petroleum that is produced in New York is obtained by water flooding, the practice of which began about 1920, when the annual output of the State had fallen to less than 1,000,000 barrels. Flooding was gradually extended until 1937, when New York produced about 5,500,000 barrels of oil, which was more than it had produced in any one year since 1882 in the period of flush production. In the 5-year period, 1934–38, no new outstanding oil field was discovered in New York, although several natural-gas fields were discovered in the deep-lying Oriskany sandstone, of Lower Devonian age. In

1938, as a consequence of the widespread business depression, the reduced price of crude oil, and proration, field activity was curtailed, and the output of petroleum in New York was 433,000 barrels less than in 1937.

### PENNSYLVANIA

During the years 1934–37 the production of petroleum in Pennsylvania increased from 14,478,000 to 19,189,000 barrels. The output in 1937 was more than Pennsylvania had produced in any other year since 1897. The peak production for the State was attained in 1891, when the output was 31,424,000 barrels. The gain in production in 1934–37 was due chiefly to the increased practice of water flooding in the Bradford field, although it was due in part to the growing use of methods of rejuvenating the old fields south of Bradford by the application of air or gas under pressure to the lenticular sands. New fields are occasionally discovered in Pennsylvania by finding oil in areas that were missed by previous drilling, but such discoveries are rare and seldom are of much importance. An example is the discovery in 1937 of the Music Mountain field, 9 miles southwest of Bradford. The productive zone was a "stray" sand 300 feet above the Bradford Third sand. The initial daily production of some wells in this field was reported to be between 4,000 and 6,000 barrels, but the producing area proved to be only about 300 acres. In 1938, as an effect of the business depression, a cut of 30 percent in the price of crude oil resulted in a decline in activity in the oil fields of Pennsylvania, and production for the year decreased to 17,426,000 barrels.

The discovery of natural gas in the Oriskany sandstone, of Lower Devonian age, in several widely separated areas in the Appalachian region, has led to a campaign of deep drilling which has thrown light on the stratigraphy and structure of the deep-lying rocks. Also, geophysical surveys have been conducted during the last few years, but the results have not been made public. Although several natural-gas fields have been discovered in the Oriskany sandstone, oil in commercial quantity has not been found in Pennsylvania in the deeply buried rocks, possibly because cementation has reduced their porosity and permeability beyond the critical point.

### WEST VIRGINIA

In 1934 the production of petroleum in West Virginia exceeded the output in 1933 but during the years 1935 to 1938 the production continued the decline which had been in progress for many years, and the annual output of the State fell from 4,095,000 to 3,684,000 barrels in the 4-year period. The practice of water flooding, which has been so successful in New York and Pennsylvania, has not yet become effective in West Virginia, apparently because of unfavorable sand permeability. Repressuring with air or gas and the use of acid in calcareous reservoir rocks, however, have been locally successful but not sufficiently so to stop the general decline.

Several small new oil-producing areas have been opened up in the shallow sands, notably the Pike pool, in Ritchie County. In this pool, which is only about 200 acres in extent, the initial daily output of the wells ranged from 5 to 650 barrels. Small oil wells have been brought in in Pleasants, Calhoun, Lincoln, Boone, and other counties. In the autumn of 1934 a well was drilled on the Burdette farm in Kanawha County southeast of Charleston, which had an initial daily production of about 150 barrels of oil from the Oriskany sandstone. This is the only Oriskany sand oil well thus far found in West Virginia. The drilling which followed failed to find more oil but opened up large gas-producing areas in Kanawha and Jackson Counties. Other deep-lying sands, which may be oil bearing if they are sufficiently porous, are the Onondaga limestone, the Newburg, a porous phase of the Lockport dolomite, of Silurian age, the so-called Clinton sand (the "White" Medina sand of New York), and the Trenton limestone.

### OHIO

Production of petroleum in Ohio during the years 1934–38 declined from 4,234,000 to 3,298,000 barrels. No outstanding new oil fields were discovered, although drilling in search of oil in the Oriskany sandstone discovered a gas field in Columbiana County. Repressuring with air and natural gas in the shallow sand fields of southeastern Ohio has been carried on for many years, but the resulting increased production of oil has not been sufficient to overcome the general decline. It is reported that the first successful repressuring of the deep-lying "Clinton" (Medina) sand in Ohio was undertaken in 1934 in Coal Township, Perry County. Eight wells were repressured with natural gas. At the beginning the combined output of the wells was 20 barrels a week, and at the end of 12 months the production had increased to 250 barrels a week.

## KENTUCKY

Petroleum production in Kentucky increased from 4,860,000 barrels in 1934 to 5,821,000 barrels in 1938. The significant development during the period was the discovery of 17 new fields in western Kentucky. Of the new discoveries, 4 resulted from random drilling, 12 from surface and subsurface investigation, and 1 from geophysical investigation.

TABLE 8.—*Wells drilled in Kentucky in 1937 and 1938*

| Year | Total | Oil | Gas | Dry |
|---|---|---|---|---|
| 1937 | 834 | 407 | 193 | 234 |
| 1938 | 889 | 484 | 91 | 314 |

The percentage of successful wells is high, because most of the drilling was done in known productive areas.

In eastern Kentucky the total production for 1938 was more than 2,000,000 barrels, an increase of 150,000 barrels over 1937 and of 250,000 barrels over 1936. About 25 new producing wells in the Corniferous (Onondaga limestone, Middle Devonian) were drilled in the Ida May field, in Lee County, in 1934. A 210-acre field was developed in 1937 in Martin County, where oil was found at a depth of 1,300 feet in the Maxon sand of Mississippian age, in buried outliers on the pre-Pennsylvanian surface. Production in this field to the end of 1938 totaled 118,315 barrels. In Floyd County near Betsy Lane a small production was obtained from the Mississippian limestones. About 150 new wells were drilled in the Big Sinking field in the normal course of development, and an increase in production followed the drilling of 50 inside locations. In addition, the field was extended a little toward the west. The general introduction of repressuring methods, however, was the largest factor in the eastern Kentucky development. Production increased over 100 percent in many of the old fields, and estimates of ultimate recovery were enlarged.

In 1938 western Kentucky produced more than 3,000,000 barrels, nearly 60 percent of the total for the State, and it probably will maintain a dominant position in the immediate future. The western Kentucky basin is an extension of the Illinois basin. Producing zones include scattered sands in the lower Pennsylvanian; the Jett, Jones, Barlow, and Bethel sands of the Chester group; the Ste. Genevieve limestone; and the older limestones and dolomites immediately below the Chattanooga shale. Most of the production comes from sands in the Chester, but the introduction of the rotary drill into Kentucky in 1938 and the general tendency toward deeper drilling make testing of the older strata inevitable.

An important structural feature in western Kentucky is the Rough Creek fault zone, which extends east and west across the basin. Well-defined structural features in and south of the fault zone, hitherto ignored by operators, have been the center of much recent activity. In 1935 in the Livermore field, McLean County, oil was obtained at a depth of 1,400 feet from a lens of Bethel sand on a plunging anticline in a horst. The total output of 158 wells in this field to the end of 1938 was over 1,300,000 barrels. Bates Knob, a faulted anticline 6 miles southwest of Livermore, was drilled in 1936 and the production obtained there from the Barlow sand at a depth of 1,600 feet was about 200,000 barrels by the end of 1938. The Hackett and Island fields, each of which produced more than 200,000 barrels in 1938 alone, were discovered near Livermore in 1937.

In the Fordsville area, Ohio County, drilling proceeded throughout the 5-year period following 1933. Three new areas, each 200 to 300 acres in extent, were discovered in 1934. Initial yields as high as 200 barrels a day were reported from the Jett sand of the Chester group, at depths of 400 feet, and, as a result 200 wells were completed the following year. The shallow production from this area, however, does not promise any great addition to the future petroleum supply of the State.

The Birk City field, discovered in 1938 during a period of intensive exploration in the deeper part of the western Kentucky basin, covers about 1,500 acres in Henderson and Daviess Counties. The production, all from the McClosky sand (Ste. Genevieve limestone), amounted to 792,000 barrels during 8 months of 1938. The producing zone lies along a flattened part of the axis of the southward-plunging Curdsville anticline, at a depth of 1,800 feet. After the Birk City development nine promising small fields were discovered in Butler, Ohio, Henderson, and Webster Counties during the second half of 1938, and further drilling is in progress in the central part of the basin.

In southern Kentucky some revival of interest in the 40-year-old Wayne County field occurred in 1936, when three wells were deepened and oil was found in the Sunnybrook sand, of Ordovician age. One well had an initial yield of 5,000 barrels a day, but the decline was rapid, and production settled to 50 barrels a day. This same sand has been productive in Cumberland County, to the west, and in the northeastern Highland Rim area, in Tennessee.

The proved reserves of Kentucky have kept pace with the annual production, and it can be stated with reasonable certainty that the ultimate recovery will exceed the most recent estimate of 37,545,000 barrels[11] by many millions of barrels.

### TENNESSEE

During the period 1934–38 Tennessee produced 133,000 barrels of oil, bringing the total since production began in 1866 to 545,336 barrels. Recent activity has centered in the northeastern Highland Rim province in Clay, Jackson, Overton, Pickett, and Fentress Counties, where 106 new wells were drilled and 7 new producing areas were discovered during the 5-year period.

TABLE 9.—*New fields discovered in Tennessee, 1934–38*

| Field and county | Date discovered | Production (barrels) | | Number of wells | Depth to oil horizon (in feet) |
|---|---|---|---|---|---|
| | | 1937 | 1938 | | |
| Hargrove, Clay | February 1937 | 10, 250 | 1, 250 | 4 | 700 |
| Beaty, Fentress | June 1937 | 1, 000 | 1, 000 | 1 | 640 |
| Pine Branch, Clay | August 1937 | 6, 993 | 12, 000 | 5 | 500 |
| Goodpasture Bend, Clay | June 1937 | 500 | 7, 300 | 2 | 465 |
| Arcott School, Clay | May 1938 | | 4, 000 | 3 | 450 |
| Turkey Creek, Clay | June 1938 | | 400 | 1 | 450 |
| Celina, Clay | December 1938 | | 285 | 1 | 240 |
| Total | | 18, 993 | 26, 235 | 17 | |

Oil occurs under similar conditions in all these fields. The production usually is confined to small anticlines in the fractured and fissured Tinsleys Bottom and Sunnybrook limestones, of Middle Ordovician age. The average life of the wells is less than 5 years and production declines rapidly. Initial production, however, is frequently as high as 100 barrels a day, and drilling is profitable because the producing zone is less than 1,000 feet below the surface. This has led to indiscriminate drilling and an unusually high percentage of dry holes.

There was little activity in the adjoining Cumberland Plateau fields in Scott and Morgan Counties, where oil is obtained from Mississippian limestones. However, the decline in production there has been arrested by the use of acid in old and abandoned wells, and an active leasing campaign in 1938 suggests that there may be additional drilling in 1939.

In western Tennessee 11 of the 16 or more wells drilled during the period penetrated the sedimentary rocks of Coastal Plain areas and entered the Paleozoic basement, which is 2,500 feet below the surface in the northwestern part of the State. Although there has been no production, interest in the region is unabated, and there was considerable geophysical work and leasing activity there in 1938.

Eleven recent tests of the Lower Ordovician sandy zones, which have been correlated with the St. Peter sandstone, yielded only shows of oil and gas. The number of dry holes drilled into these zones is now 50 or more, all located in or adjoining the Central basin, where the Cincinnati arch has brought the Lower Ordovician close to the surface. However, few of these wells were drilled in areas of closed structure, and the lower zones are still inadequately tested.

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[11] American Petroleum Institute, Committee on Petroleum Reserves, American Petroleum Institute Quarterly, vol. 9, No. 2, pp. 7–8, April 1939.

TABLE 10.—*Wells drilled and oil produced in Tennessee, 1934–38*

| Year | Production (barrels) | New wells | | | | Wildcat wells | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number | Oil | Gas | Dry | Number | Oil | Gas | Dry |
| 1934 | 15,000 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 1935 | 20,000 | 16 | 2 | 0 | 14 | ------ | ------ | ------ | ------ |
| 1936 | 20,000 | 14 | 1 | 0 | 13 | 12 | 0 | 0 | 12 |
| 1937 | 37,000 | 47 | 14 | 5 | 28 | 31 | 4 | 1 | 26 |
| 1938 | 41,000 | 80 | 16 | 3 | 61 | 62 | 3 | 0 | 59 |
| Total | 133,000 | 157 | 33 | 8 | 116 | 105 | 7 | 1 | 97 |

## MICHIGAN

Since the discovery of oil on an anticline in the Saginaw field in 1925, productive oil pools have been developed in several counties in the lower peninsula of Michigan. The most productive fields are now in Muskegon, Midland, Montcalm, Isabella, Gladwin, Clare, Ogemaw, Arenac, Allegan, and Van Buren Counties. In 1934 the total oil production of the State was 10,603,000 barrels, and in 1938 the production was 19,211,000 barrels. Reserves of oil in Michigan to the end of 1938 have been estimated as more than 40,000,000 barrels.

The main producing formations are porous limestones and dolomites in the Traverse, Dundee, and Detroit River (upper Monroe), of Devonian age, and the Berea and Marshall, of Mississippian age. The greater number of pools have been found in anticlines that trend northwest.

Owing to the thick covering of glacial drift over most of the lower peninsula, the detection of buried structural features has been dependent mainly upon studies of deep-well records and on shallow test-well drilling. Undoubtedly there will be much additional prospecting for oil and gas pools in the Devonian formations outward from the central part of the Michigan basin and also in the deeper Silurian and Ordovician formations in both developed and undeveloped parts of the basin, no part of which lacks oil possibilities. Some geophysical reconnaissance work has been done, especially to check core-drill "highs," but up to 1938 geophysical work had not proved entirely satisfactory.

In 1934 Michigan produced 10,603,000 barrels of oil from about 979 wells. The central Michigan area yielded the greater part of this production. Oil was found and produced in the Traverse formation in the Hart district, in Oceana County, and at Edmore, in Montcalm County. Thirty wells were completed in the old West Branch field, in Ogemaw County, where about 3,000 acres has proved productive from the Traverse and the Dundee. In Beaverton Township, Gladwin County, oil was found in the Dundee at a depth of 3,830 feet. The discovery well had an initial daily production of 70 barrels, which decreased to 25 barrels.

In March 1935 oil was discovered in the Crystal field, in Crystal Township, Montcalm County, and the first well had an initial production of 5,000 barrels daily. During the year 88 wells were drilled in the field, but it reached its peak in October, when water encroachment caused a rapid decline. The oil is produced from the Dundee at depths around 3,100 feet. The field is on a flat-topped anticline on one of the principal northwest-southeast trends common to the Michigan basin.

The outstanding deep test in 1935 was on the Howell fold in Livingston County. The well was drilled through the Trenton into the St. Peter to a depth of 5,890 feet, where it struck salt water. Early in the year a well was drilled in Sherman Township, Newago County, which reached the Trenton and went to a depth of 6 674 feet.

The discovery of the Buckeye or South Buckeye field in Buckeye Township, Gladwin County, was one of the most important developments for the year 1936. The first well was drilled in July and found oil in the Dundee at about 3,600 feet. The discovery of this field was due to the drilling of shallow test wells to the Marshall across the strike of possible structural trends. Production has been obtained from one to three zones. Oil was discovered also in an unusually porous zone in the Dundee at a depth of about 2,500 feet, in Clayton Township, Arenac County, on the Ogemaw-Arenac anticline. New production was developed in the Detroit River dolomite in Sherman Township, Isabella County, and oil was discovered in Winfield Township, Montcalm County.

During 1936 test holes were drilled in 45 counties in the lower peninsula. The deepest one, in sec. 18, T. 32 N., R. 6 E., was drilled to a depth of 5,665 feet and found the St. Peter sandstone dry. Another test, in sec. 35, T. 7 N., R. 9 W., reached a depth of 5,575 feet and ended in the Trenton limestone.

In February 1937 the Salem oil pool, in Allegan County, southwestern Michigan, was discovered by a 100-barrel well in sec. 16, T. 4 N., R. 13 W. During the year 54 wells producing from the Traverse limestone at depths around 1,600 feet were drilled. It was reported that no dry holes had been drilled within the area of productive closure of the pool.

The discovery well in the North Buckeye pool was completed in January 1937 with an initial daily production of 1,292 barrels from a depth of 3,616 feet in the Dundee. Both the North and South Buckeye pools in Gladwin County were areas of active development during 1937, and continued prospecting along the Buckeye "trend" resulted in the development of a 125-barrel well in the Dundee at 3,670 feet 6 miles southeast of the South Buckeye pool. The first oil well of commercial importance in the Sherman pool, in Isabella County, had an initial production (after acid treatment) of 672 barrels a day at a depth of 3,656 feet from the Detroit River dolomite (upper Monroe of older reports). Twenty-one new producers were drilled in the Ravenna field in Muskegon County, which is the only one in the State in which production is obtained from the Berea sandstone. Oil was discovered in the Traverse in Adams Township, Arenac County.

The year 1938 was notable in discoveries of oil pools in the Traverse in Allegan and Van Buren Counties, southwestern Michigan, that renewed interest in the possibilities of production in the Traverse, as well as in the older Monroe formations. Prior to this year the Dundee was the really important oil-producing formation. Even in the central part of the Michigan Basin wells need not be drilled to depths greater than about 3,900 to 4,500 feet in order to test the Monroe section, which includes the upper Monroe, the Detroit River and Sylvania, and the lower Monroe or Bass Islands. Below the Monroe section are the formations of Silurian and Ordovician age, which have been reached by only a few wells in the State.

Among the important developments in 1938 was the discovery in March of the Monterey pool, Allegan County, by a well that had an initial daily production of 300 barrels from the Traverse at a depth of about 1,615 feet. The production increased to 750 barrels after acid treatment. This pool is on a northeast-southwest fold.

The Door pool, Allegan County, had its first commercially productive well in March 1938 from the top of the Traverse at 1,625 feet. The initial production was 250 barrels a day, after acid treatment. The greatest extension of this field is along a northwest-southeast fold, and apparently there are three separate producing areas on three small crossfolds.

The Diamond Springs and Overisel pools, in Allegan County, and the Bloomingdale pool, in Van Buren County, all producing from the Traverse, were also discovered in 1938.

The Freeman-Redding or Van Horn field, in Clare County, was discovered in July 1938, and by the middle of December it had 40 producing wells with average daily runs of 9,500 barrels. The oil here is obtained from porous limestone, the Dundee (?) or Monroe, at depths around 3 900 to 4 000 feet, and it has been estimated that the field has a reserve of 8,000,000 barrels. The anticline on which the field is located plunges southeastward instead of northwestward like the folds in Midland and Isabella Counties.

The Edenville pool, in Midland County, was discovered in 1938. Oil was found in the Walker-Wyoming district at a depth of more than 1,700 feet in the Traverse, and the initial production was 200 barrels daily. This pool was discovered as a result of geologic studies and test drilling.

In the Thumb district oil was discovered in North Akron Township, Tuscola County. The initial production was 13 barrels daily from the Monroe. Although some oil had previously been found in the upper part of the Monroe, this discovery is the first at so great a depth as 495 feet below the top of the formation.

Throughout Michigan in 1938 more than 560 wells were completed, averaging 450 barrels in initial daily production per well. Of a total of 176 wildcat wells drilled during the year, 21 produced oil. Of these wildcat wells 118 were drilled on geologic information, 15 of which were productive; 3 were drilled as the result of geophysical work, of which 1 was productive; and 55 were drilled without technical information, of which 5 were productive.

## ILLINOIS

Illinois, which has been an important oil producer for about 40 years, has been an area of especially active petroleum development in the 5-year period 1934–38. In 1934 and 1935 only one small area of new production was discovered each year. In 1936 the more productive Bartelso field was brought in. In March 1937 production was obtained simultaneously in the Cisne and Clay City fields by wildcat wells drilled on anticlines located by seismograph work. These discoveries spurred drilling activity in the Illinois basin that resulted in the discovery of a total of 8 new pools in 1937 and 15 new pools in 1938. According to estimates of reserves by the American Petroleum Institute, plus production of the new fields in 1937 and 1938, about 225,000,000 barrels of oil was added to our petroleum supply by those new fields.

TABLE 11.—*Production, wells drilled, and results of drilling in Illinois, 1934–38*

| Year | Production (barrels) | Wells drilled | | | | Wildcat wells | | | | New oil fields discovered |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil | Gas | Dry | Total | Oil | Gas | Dry | Total | |
| 1934 | 4, 479, 000 | 10 | 1 | [1] 15 | 26 | 1 | 1 | 11 | 13 | 1 |
| 1935 | 4, 322, 000 | 14 | 3 | 17 | 34 | 2 | 3 | 14 | 19 | 1 |
| 1936 | 4, 475, 000 | 49 | 3 | 40 | 92 | 2 | 0 | 31 | 33 | 1 |
| 1937 | 7, 499, 000 | 284 | 3 | 160 | 447 | 19 | 0 | 108 | 127 | 8 |
| 1938 | 23, 929, 000 | 1, 984 | 26 | 529 | 2, 539 | 28 | 4 | 345 | 377 | 15 |
| Total | 44, 704, 000 | 2, 341 | 36 | 761 | 3, 138 | 52 | 8 | 509 | 569 | 26 |

[1] Includes 1 well drilled for repressuring input.

The discovery of several new fields and continued drilling in 1939 indicate that additional fields will be discovered in Illinois in the future. It is significant that in the first 6 months of 1939 Illinois produced 32,706,000 barrels of oil, which is only 1,000,000 barrels less than the peak annual production of 33,686,000 barrels, in 1908, and it has been estimated that discoveries in the first 9 months of 1939 have doubled the total reserves of Illinois as estimated for January 1, 1939.

About 98 percent of the oil produced in Illinois prior to 1934 came from fields scattered along the large La Salle anticline, in southeastern Illinois. That anticline forms the east side of the so-called Illinois Basin of the south central part of the State, from which most of the recent production has come. The remaining 2 percent of old production came from scattered fields, most of which lie in the southwestern part of the State on the west side of the basin.

The new fields are situated on anticlines and domes, most of which have been located by the seismograph, although a few, such as the New Centralia, Loudon, and Bartelso, have been discovered by drilling on surficial structural features. The Bartelso field was developed on an anticline defined many years ago in the course of cooperative geologic work between the Illinois and Federal Geological Surveys. Some others have been found by drilling in areas indicated by subsurface data and along trends. The greater part of the new production has come from the McClosky "sand," in the Ste. Genevieve limestone, of lower Mississippian age, but considerable has come from the Aux Vases, Bethel, and Cypress sands of the upper Mississippian Chester group. Some oil has also come from a sandstone in the Paint Creek formation (Chester) and from the Rosiclare sandstone member of the Ste. Genevieve limestone. In most of the basin area the surface is covered by a thin veneer of Pleistocene glacial drift underlain by about 800 to 2,000 feet of Pennsylvanian strata, beneath which in turn lie 500 to 1,200 feet of strata of Chester age, containing the Aux Vases, Bethel, and Cypress sands in the lower part and immediately overlying the Ste. Genevieve limestone, which includes the McClosky "sand."

Active petroleum development in Illinois in the period 1934–38 was confined to the Illinois Basin. In that area strata of the upper Mississippian Chester group and lower Mississippian Ste. Genevieve limestone that thicken southward are present beneath Pennsylvanian strata. North of the basin the productive Mississippian formations were removed by erosion in pre-Pennsylvanian time.

In Richland, Clay, and Wayne Counties, where about half of the new fields are situated, the fields lie along a southward-plunging, northeastward-trending anticlinal belt. The northern portion of this belt is a simple anticline which, toward the south, splits into several anticlines and synclines. A second general group of fields lies about 40 miles farther west and extends southward from Fayette County through Marion, Clinton, and Jefferson Counties. The remaining fields appear to be scattered.

In December 1938 oil was obtained in Devonian limestone in the old Sandoval field, in Marion County, which had previously produced from the Benoist (Bethel) sand of the Chester group. That production suggests that deeper drilling in existing fields might yield additional oil. The possibility of production from pre-Mississippian beds in the new fields is supported by the fact that some oil has been obtained from Devonian to Trenton (Ordovician) limestones in old fields in Illinois.

Three of the largest pools discovered in Illinois in 1937 and 1938 are the Loudon pool, in Fayette County; the Salem pool, in Marion County; and the New Centralia pool, in Clinton and Marion Counties. Brief descriptions of those pools are given below.

*Loudon pool.*—The Loudon pool, in Fayette County, is about 15 miles long, 1 to 3 miles wide, and has a proved area of about 19,000 acres. It was located by surface geologic mapping which showed a broad north-south anticline in Pennsylvanian strata, and this method was followed by seismograph work, which showed similar subsurface structure.

The surface is covered by 20 to 100 feet of glacial drift, with scattered exposures of Pennsylvanian strata in stream banks. The Pennsylvanian strata are 1,000 to 1,200 feet thick and rest unconformably on strata of the Chester group of the Mississippian series. The anticline at this locality existed as a structurally and topographically high area in pre-Pennsylvanian time, as shown by Pennsylvanian filled stream channels cut more deeply into older formations in the axial part of the anticline than on the flanks. The total stratigraphic range of Chester strata in contact with the Pennsylvanian is about 200 feet. The Chester group is 525 to 725 feet thick and contains three productive sands—the Weiler (Cypress), Stray (Paint Creek), and Benoist (Bethel). Four or five wells have also penetrated the Ste. Genevieve limestone but failed to get production in the McClosky "sand" in that formation. The discovery well also passed through the entire section of lower Mississippian strata and the Chattanooga shale and entered underlying Devonian limestones, in the upper part of which a six-barrel show was obtained after two treatments with acid.

The subsurface structure as mapped on the Glen Dean limestone of the Chester group shows a long anticline extending northeast and southwest, with a maximum closure of about 200 feet, a general southwest plunge, and more gentle dips on the southeast flank than on the northwest flank. On deeper strata the structure is similar, but the anticline is slightly sharper. No faults have been encountered.

*Salem oil field.*—The Salem oil field, in Marion County, ranked seventh in daily production in the United States during the week of January 7, 1939. It is about 7 miles long and 1 to 3½ miles wide. The field was discovered by a seismograph survey in an area covered by 40 to 60 feet of glacial drift. Beneath the drift lie about 1,100 feet of Pennsylvanian strata, which rest unconformably on about 680 feet of strata of the Chester group of the Mississippian series, which in turn overlie about 120 to 145 feet of strata in the Ste. Genevieve limestone. The oldest formation penetrated by drilling to date is the St. Louis limestone, of lower Mississippian age.

The producing zones are the Benoist sand (Bethel), the Aux Vases sand, and the McClosky "sand" (Ste. Genevieve), all of Mississippian age, but the greater part of the development to date has been in the Benoist sand. All three of the sands appear to be productive over the entire field, but their productivity is local where low porosities are encountered.

The structure of the field as mapped on the top of the Benoist sand is that of a simple, slightly irregular anticline that trends slightly north of east, has a structural closure of more than 225 feet, and has dips on the west flank about twice as steep as those on the east flank.

*New Centralia oil field.*—The New Centralia oil field, in Clinton and Marion Counties, was discovered in November 1937 and has a proved area of 2,600 acres and an average daily production of more than 6,000 barrels. It lies 2 to 3 miles west of the older Centralia pool, which was opened in 1908 as a result of surface and subsurface geologic work. The new pool was opened on structure indicated by a reflection seismograph survey.

The surface of the New Centralia pool is covered by glacial drift a few feet to 150 feet thick, beneath which lie about 800 feet of Pennsylvania strata, which in turn overlie the Chester group, from which the production is obtained. The principal production comes from the Benoist sand, of the lower part of the Chester, and additional oil is obtained from the Cypress sandstone, in the middle part of the Chester. A few test holes drilled through the Chester group into the underlying Ste. Genevieve limestone have been unsuccessful.

The field lies on the crest of an anticline about 7 miles long that tapers from about 3 miles in width at the north end to about 1 mile at the south end, as contoured on the top of the Benoist sand. The producing area is smaller, about 6 miles long and 1 mile wide. The structural closure on the top of the Benoist sand is about 110 feet, and dips are steeper on the east flank of the anticline than on the ends or the west flank.

This field serves to illustrate the shallowness of many of the recently discovered producing sands in Illinois, because the 531 producing wells in June 1939 had an average depth of only 1,370 feet.

### INDIANA

Petroleum developments in Indiana in the period 1934–38 were not extensive. Four new fields were brought in—Blairsville, in Posey and Vanderburgh Counties, in 1934; Prairie Creek, in Vigo County, in 1937; and Heusler, in Posey County; and Griffin, in Gibson County, in 1938. The Blairsville pool produces from the Mansfield sand, of lower Pennsylvanian age, has a total proved area of about 350 acres, and produced to the end of 1938 about 141,000 barrels of oil. The Prairie Creek field produces from Devonian and Silurian limestones at depths of about 2,000 feet, has a total proved area of about 690 acres, and produced to January 1, 1939, about 160,000 barrels. The Heusler field produces from the Tar Springs sand of the Chester group (upper Mississippian), has a proved area of about 200 acres, and produced to January 1, 1939, about 27,000 barrels. The Griffin pool, discovered late in 1938, produces from the McClosky "sand" of the Ste. Genevieve limestone (lower Mississippian). It has not yet been developed, and its extent has not been established. Two of the fields were discovered by seismograph surveys, one by surface and subsurface geology, and one by wildcatting. All the fields are situated on small anticlines.

About 85 percent of the total production in Indiana prior to 1934 came from the Trenton fields in the northeastern part of the State, but by 1933 those fields had declined so much that 97 percent of the annual production came from scattered fields in the southwestern part of the State, where also the greater part of the activity in the period 1934–38 took place.

Some additions to the oil supply of Indiana have been made by deepening wells in old gas fields, such as the Francisco field, in Gibson County, which had only 80 acres of proved oil land in 1934 but which, by deeper drilling in the following years, has been expanded to 600 acres of proved oil land. Some additional oil production has been obtained by inside drilling or repressuring with compressed air or natural gas, in old fields such as the Trenton fields, and by treatment with acid in some of the old fields producing from limestone.

TABLE 12.—*Oil produced, wells drilled, and results of drilling in Indiana, 1934–38*

| Year | Production (barrels) | Wells drilled | | | | Wildcat wells | | | | New oil fields discovered |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil | Gas | Dry | Total | Oil | Gas | Dry | Total | |
| 1934 | 838, 000 | 69 | 41 | 76 | 186 | -------- | -------- | -------- | -------- | 1 |
| 1935 | 777, 000 | 48 | 61 | 115 | 224 | 18 | 12 | 87 | 117 | -------- |
| 1936 | 822, 000 | 45 | 53 | 96 | 194 | 4 | 10 | 42 | 56 | -------- |
| 1937 | 844, 000 | 39 | 39 | 56 | 134 | 1 | 3 | 32 | 36 | 1 |
| 1938 | 969, 000 | 48 | 41 | 70 | 159 | 3 | 3 | 36 | 42 | 2 |
| Total | 4, 250, 000 | 249 | 235 | 413 | 897 | -------- | -------- | -------- | -------- | 4 |

In the last 2 years, as a result of the numerous new discoveries in the Illinois Basin to the west, considerable geologic mapping, geophysical prospecting, and leasing have been done in the southwestern Indiana coal basin as far east as Crawford and Monroe Counties and north to Benton County. The sands of the Chester group and Ste. Genevieve limestone that are productive in Illinois have yielded oil at a few places in Indiana, and it is certain that all structural traps that can be located in the area of their occurrence in southwestern Indiana will be fully tested in the near future. Additional wildcat drilling will also be carried down to Devonian, Silurian, and Ordovician limestones over an even more extensive area. It is to be hoped that such increased exploratory drilling will result in the discovery of new oil pools.

## Midcontinent Region

(Arkansas, Kansas, Louisiana, Mississippi, Missouri, New Mexico, Oklahoma, and Texas)

### ARKANSAS

Oil production in Arkansas reached its peak in 1925, when 77,000,000 barrels of oil was produced. Thereafter there was a gradual and uninterrupted decline to a production of only 11,500,000 barrels in 1933, and the decline continued in 1934, 1935, and 1936, the production in 1936 amounting to only 10,500,000 barrels. Even more discouraging was the failure to find new fields capable of large production. In 1934 the Camden field was discovered, but in 1935 it produced only 24,000 barrels of oil. A new producing zone was also discovered in the Champagnolle field in 1934. In 1935, however, neither new fields nor new productive zones in old fields were discovered. In 1936 the newly discovered Troy field produced less than 16,000 barrels, although it increased its production to nearly 300,000 barrels in 1937.

In 1934 the oil produced in Arkansas was obtained from rocks of Upper Cretaceous age and in a few fields from zones in the Travis Peak formation, in the lower part of the Lower Cretaceous Trinity group. Deep drilling in southern Arkansas and northern Louisiana had, however, revealed the existence of an underlying lower marine series, later to be called the Cotton Valley formation. Below that, in turn, are now known the Buckner formation of anhydrite and dolomitic limestone, the Smackover limestone, and the Eagle Mills formation of rock salt, red shale, and red sandstone.

In May 1936 a new phase of oil exploration in southern Arkansas was begun in the Snow Hill area of the Smackover field, when oil was obtained from the Smackover limestone. This limestone subsequently furnished the producing zone in the Buckner field, discovered in 1937, and the Magnolia, Village, and Atlanta fields, discovered in 1938. Other deep zones, however, have contributed much more to the increase in production in 1937 and 1938—notably the lower Glen Rose in the Rodessa field, which was extended into Arkansas in June 1937, and sands in the Cotton Valley formation in the Schuler field, discovered in April 1937. The small Falcon field, producing from Upper Cretaceous rocks, was discovered in 1938.

The deep drilling of the 5-year period has been effective in increasing production and adding greatly to the proved reserves, and doubtless additional pools will be found in Lower Cretaceous and older Mesozoic zones. The proved reserves of January 1, 1935, as estimated by the American Petroleum Institute, amounted to 103,000,000 barrels. On January 1, 1939, the preliminary estimate of the American Petroleum Institute was that the proved reserves amounted to 188 246,000 barrels. It is of special interest that the Magnolia field, in Columbia County, discovered in the early part of 1938, was largely expanded by intensive drilling in 1939, and according to a recent estimate[12] the reserves of the Magnolia field alone amount to 150,000,000 barrels. For August and September 1939 the daily average production has been set at 13,500 barrels, and about 12,000,000 cubic feet of gas is being produced daily in the field. The production comes from the Reynolds oolitic member of the Smackover limestone at depths of more than 7,000 feet on an elongated east-west anticline. The productive zone has a very steep dip on the north side of the field and a lower dip on the south side.

Geophysical methods have been widely utilized in locating the deep-seated structural features, chiefly anticlinal, that have been found productive, although

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[12] Oil and Gas Journal, August 17, 1939, p. 45.

most of the deep structural features are reflected in the less-sharply deformed overlying Upper Cretaceous and Tertiary beds. The more favorable areas may therefore be selected by the accurate correlation of logs of shallow wells. In a few fields the accumulation is apparently controlled in part by lenses of sand or lenses of greater porosity in limestone. The discovery of additional fields on both structural and stratigraphic traps may be expected.

The long-range picture is at present not so favorable. On the basis of present knowledge the rocks below the Smackover limestone are not likely sources of oil and gas and the top of the rock salt of the Eagle Mills formation is taken to be the economic limit for oil prospecting. Folded Paleozoic or metamorphic rocks probably underlie the Eagle Mills. All the fields at present known lie in six counties in the southwestern part of the State. In 1934 some hope was entertained that the Coastal Plain area in Arkansas east and northeast of these counties might furnish producing wells, but exploratory wells drilled in the eastern part of the State since then have been uniformly unsuccessful.

A table summarizing the production and development for the period 1934–38 follows:

TABLE 13.—*Annual oil production, number of wells drilled, number of new oil fields, and number of fields in which one or more new producing zones were found in Arkansas, 1934–38*

[Data except production from American Institute of Mines and Metalurgical Engineering transcript]

| Year | Production (thousands of barrels) | Wells drilled | | | | Wildcat wells | | | | Number of new fields | Number of old fields in which 1 or more new producing zones were found |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil | Gas | Dry | Total | Oil | Gas | Dry | Total | | |
| 1934 | 11, 182 | 36 | ----- | ----- | ----- | 2 | ----- | ----- | ----- | 1 | 1 |
| 1935 | 11, 008 | 44 | 2 | 77 | 123 | 0 | 1 | 49 | 50 | 0 | 0 |
| 1936 | 10, 469 | 26 | 3 | 55 | 84 | 2 | 0 | 41 | 43 | 1 | 1 |
| 1937 | 11, 764 | 103 | 6 | 68 | 177 | 4 | 0 | 52 | 56 | 3 | 1 |
| 1938 | 18, 077 | 199 | 1 | 43 | 243 | 4 | 0 | 25 | 29 | 4 | 0 |

## KANSAS

The amount of oil produced annually in Kansas during the period 1934–38 increased each year through 1937 but decreased considerably in 1938. The total annual production as reported by the Bureau of Mines is shown by years in the following table. The annual production equals the total amount allotted to Kansas by the crude-oil purchasers. The rate of production in most new fields was maintained at a small percent of their capacities to produce.

TABLE 14.—*Reserves and annual production of oil in Kansas, 1934–38*

| Year | Proved reserves at beginning of year (barrels) | Production during year (barrels) [1] | Year | Proved reserves at beginning of year (barrels) | Production during year (barrels )[1] |
|---|---|---|---|---|---|
| 1934 | [2] 470, 000, 000 | 46, 482, 000 | 1938 | [3] 607, 000, 000 | 59, 587, 000 |
| 1935 | [2] 490, 000, 000 | 54, 843, 000 | 1939 | [3] [4] 613, 230, 000 | ---------- |
| 1936 | [2] 525, 000, 000 | 58, 317, 000 | | | |
| 1937 | [3] 590, 000, 000 | 70, 761, 000 | Total | ---------- | 289, 990, 000 |

[1] Bureau of Mines.

[2] From unpublished sources believed to be reliable.

[3] American Petroleum Institute.

[4] Some operators believe this estimate should be increased by about 140,000,000 barrels due to discoveries of new reserves from 1936 to 1938.

*Reserves.*—The proved reserves in Kansas were increased by 143,230,000 barrels from the end of 1933 to the end of 1938, in spite of the fact that a total of 289,990,000 barrels was withdrawn during the 5 years. Most of the new oil added to the proved reserves during the 5-year period resulted from the discoveries of new oil pools, a considerable part from the discovery of new producing zones in old pools, and a part from revision upward from year to year of the estimates of available oil in old fields. Each year during the period the amount of oil discovered in Kansas exceeded the amount withdrawn.

*Oil wells, gas wells, and dry holes.*—The following table shows the number of oil wells, gas wells, and dry holes drilled in Kansas in the period 1934–38:

TABLE 15.—*Wells drilled in Kansas, 1934–38* [1]

| Year | Oil wells | Gas wells | Dry holes | Total |
|---|---|---|---|---|
| 1934 | 591 | 22 | 222 | 835 |
| 1935 | 890 | 39 | 281 | 1, 210 |
| 1936 | 1, 214 | 61 | 446 | 1, 721 |
| 1937 | 1. 867 | 357 | 606 | 2, 830 |
| 1938 | 1, 108 | 200 | 402 | 1, 710 |
| Total | 5, 670 | 679 | 1, 957 | 8, 306 |

[1] U. S. Bureau of Mines.

Activity in drilling wells increased at a rapid rate from 1934 through 1937. In 1938 wildcat drilling and particularly development of fields were sharply curtailed, owing to a lack of adequate crude-oil market; most operators drilled only wells made necessary by expiring leases or by offset-well obligations. It is noteworthy, however, that the curtailment was not caused by any lack of success in wildcat ventures. The percentage of successful wildcats remained high.

*Discoveries and developments.*—The following table shows the number of new oil fields, new gas fields, and new zones in old fields discovered in Kansas from 1934 to 1938 and indicates the dominant methods used in locating the sites for the discoveries. The statistics compiled in the table omit that part of Kansas lying east of R. 6 E.—an area that contains many old oil and gas fields in sands of the Pennsylvanian series. The total amount of oil produced from the new discoveries in this region is small.

TABLE 16.—*New pools and methods of discovery in Kansas, 1934–38*

| | 1934 | 1935 | 1936 | 1937 | 1938 |
|---|---|---|---|---|---|
| New oil fields | 29 | 42 | 54 | 57 | 49 |
| New gas fields | 4 | 3 | 7 | ? | 2 |
| New zones in old fields | 3 | 6 | ? | 8 | 16 |
| Methods of discovery of new fields (incomplete): | | | | | |
| Surface geology | 6 | 3 | 2 | 7 | 17 |
| Subsurface geology | 6 | 19 | 9 | 12 | |
| Core drill | 12 | 6 | 6 | 13 | 10 |
| Seismograph | 3 | 2 | 10 | 8 | 6 |
| Subsurface geology and seismograph | ------ | 3 | ------ | ------ | 2 |
| Core drill and seismograph | ------ | ------ | 3 | ------ | ------ |
| Core drill and surface geology | ------ | 2 | ------ | ------ | ------ |
| Core drill and subsurface geology | ------ | 5 | 2 | ------ | ------ |
| Wildcat with little or no geologic or geophysical advice | 4 | 5 | 8 | 8 | 8 |

The table shows that discoveries of new fields in Kansas during the last 4 years of the 5-year period were at the rate of about one a week. It is noteworthy that the principal methods used in locating the new oil fields were surface and subsurface geology, aided in many areas by core drilling.

The greatly increased activity in exploratory drilling in 1934 over 1933 (not shown in table) is attributed to the fact that leases on many large blocks were about to expire. Most of the drilling was done in western Kansas; as a result, Rice, Russell, Reno, and Barton Counties led in new pools discovered. The main development of old pools took place in McPherson, Rice, Reno, Russell, Sedgwick, Harvey, and other counties in western Kansas. Acid treatment was applied to many wells in old and new pools and had remarkable success in increasing the rates of yields.

Drilling activity continued in western Kansas in 1935 and was extended even farther west than in 1934. Russell County led with the most discoveries; Rice, Barton, Ellis, Sumner, and Harvey Counties each were rewarded with three to six new pools. Development of old pools continued, particularly in Rice, Reno, Ellsworth, Russell, and McPherson Counties.

In 1936 Ellis, Rice, and Russell Counties ranked highest in the number of new pools discovered, and Barton County ranked next. Important gas discoveries were made in Finney and Haskell Counties. Rapid development took place in and near the Trapp pool in Russell County, in the Silica field in Barton County, in the Lorraine pool in southern Ellsworth County, and in several small fields in Ellis County. Many wells were drilled to be used solely for the disposal of salt water. Some revival of drilling took place in the old oil fields in southeastern Kansas, where the Arbuckle limestone, which lies below the main producing zones, was found to be oil-bearing; also several water-flooding and repressuring operations in old fields were under way here.

New oil pools were discovered in 13 counties in 1937, which was probably the most active year for oil and gas exploration in the history of the State. Rice County ranked first, with 7 new pools; Ellis and Barton Counties each had 6 new pools; and Russell County had 4. Many wildcat wells were drilled in Stafford County, where oil in the Misener sand, a new oil-bearing zone for western Kansas, was found in the Zenith pool. The Wethered pool, in the Arbuckle limestone, was discovered in Cowley County. The Trapp, Bemis, and Silica fields, in the Arbuckle limestone, which are the 3 largest oil fields in Kansas, were rapidly developed.

The production of gas in Kansas reached a total of 60,000,000,000 cubic feet in 1938, which, except for 1908, when 80,000,000,000 cubic feet were produced, is the State's largest yearly total. Most of the gas was derived from the Hugoton field, whose total area is more than 2,000 square miles; some was produced from the Otis field. The Zenith, Trapp, Silica, and Bemis oil pools were actively developed. Great interest in leasing and geologic investigation was shown in the Forest City Basin in far northeastern Kansas.

*Areas of active interest and possibilities for new pools.*—The principal oil discoveries and the main prospecting and leasing in Kansas during the period 1934–38 have been on the central Kansas uplift (Barton arch), a broad northwestward-trending area in which the rocks are structurally higher than in the large basins that flank it on the northeast and southwest. This broad arch occupies all or parts of Rice, Reno, Ellsworth, Barton, Russell, Ellis, Rush, Trego, Rooks, Graham, and Norton Counties. Throughout much of the area containing the oil pools Pennsylvanian rocks lie directly on the Arbuckle limestone (siliceous lime), of Cambrian and Ordovician age, which is the main oil-bearing formation. The Simpson formation and the Viola and Hunton limestones are present on the flanks of the arch and are believed to extend throughout much of the western two-thirds of the State. Other oil-bearing zones occur in the Lansing-Kansas City strata and in other parts of the Pennsylvanian series, which is present throughout the region, and in the Mississippi lime, which is present only on the flanks of the arch. These favorable geologic conditions and the success of exploratory effort in recent years will doubtless keep this region among the active areas for years to come.

During the 5-year period 1934–38 leasing activity was extended northwestward through Graham and Rooks Counties; much acreage was relinquished in Lane, Grove, Scott, Finney, Ford, Clark, and Comanche Counties. In the later part of the period from 80 to 90 percent of the total area of Rice, Reno, Lyons, Barton, Stafford, and Pratt Counties and the southwest half of Russell, Ellis, and Rooks Counties was under lease; from 50 to 70 percent of the area of Barber, Edwards, Pawnee, Rush, Ness, Trego, and Graham Counties was under lease. The Arbuckle limestone is the principal oil producer in this region. Eighty percent of the areas in Stephens, Grant, and Haskell Counties that are in the Hugoton gas field, were under lease; the gas occurs in Permian limestones.

An extensive leasing campaign in northwestern Missouri spread into northeastern Kansas in 1938. The Arbuckle limestone and St. Peter (Simpson) sand, rocks that are equivalent to the Viola and Hunton limes, the Mississippi lime, and beds in the Pennsylvanian are the objectives in prospecting here. No wells had been drilled by the end of 1938.

*Examples of new oil pools.*—Silica field: The Silica field is in Barton County, on the central Kansas uplift. Although the discovery well was drilled in 1931, the field was not known as a large field until the early part of the 1934–38 period, when additional wells were drilled. The oil field occupies a complex subsurface dome on which the Arbuckle limestone was deeply eroded and later buried by the uppermost beds of the Marmaton group of the Pennsylvania series. The oil occurs at a depth of 3,300 feet in a weathered porous zone, about 20 feet thick, at the top of the Arbuckle limestone. The oil-bearing zone lies below a thin conglomerate that forms the basal bed of the overlying Pennsylvanian series. Water occupies the reservoir zone on the flanks of the dome. The total area of the field is about 8,500 acres and it has 455 oil wells. Its total yield at the end of 1938 was 16,350,080 barrels, essentially all of which had been produced since 1934.

Bemis field: The Bemis field is in Ellis County, on the central Kansas uplift, in an area that contains a large inlier of the Simpson formation in the subsurface section. The field is on a complicated subsurface dome. The oil occurs at a depth of about 3,375 feet in a zone of weathered dolomite about 7 feet thick in the top of the Arbuckle limestone. A few wells produced small amounts of oil from the Simpson formation, and a few produced from the Topeka limestone in the Pennsylvanian series. The reservoir bed in the Arbuckle is overlain by the Kansas City group of the Pennsylvanian series in much of the field and by the Simpson formation in some places. The oil-bearing zone contains water on the flanks of the dome. Oil was discovered in the Topeka in 1935 and in the Arbuckle in 1936. The total area of the field is about 3,200 acres, and it has 218 wells. The total yield at the end of 1938 was 3,899,351 barrels.

### LOUISIANA

In the 5-year period 1934–38 Louisiana nearly tripled its annual production of petroleum and increased its proportion of the petroleum produced in the United States from 3.6 percent in 1934 to 7.8 percent in 1938. It became the fourth ranking State in petroleum production in 1936 and maintained that position in the following 2 years. Some of the outstanding features of production and development are summarized in the following table:

TABLE 17.—*Annual oil production, wells drilled, new fields, and fields in which new producing zones have been discovered in Louisiana, 1934–38*

| | Production (thousands of barrels)[1] | Number of wells drilled in proved fields and wildcats | | | | Number of wells drilled, wildcats alone | | | | Number of new fields | Number of fields in which one or more producing zones were found |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil | Gas | Dry | Total | Oil | Gas | Dry | Total | | |
| 1934: | | | | | | | | | | | |
| Northern Louisiana | 9,075 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 0 | 0 |
| Southern Louisiana | 23,794 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 5 | 2 |
| Total | 32,869 | 427 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 5 | 2 |
| 1935: | | | | | | | | | | | |
| Northern Louisiana | 9,554 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 1 | 0 |
| Southern Louisiana | 40,776 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 7 | 14 |
| Total | 50,330 | 348 | 104 | 251 | 703 | 7 | 4 | 110 | 121 | 8 | 14 |
| 1936: | | | | | | | | | | | |
| Northern Louisiana | 26,917 | 346 | 108 | 78 | 532 | 1 | 2 | 45 | 48 | 2 | 2 |
| Southern Louisiana | 53,574 | 255 | 7 | 135 | 397 | 4 | 1 | 45 | 50 | 5 | 12 |
| Total | 80,491 | 601 | 115 | 213 | 929 | 5 | 3 | 90 | 98 | 7 | 14 |
| 1937: | | | | | | | | | | | |
| Northern Louisiana | 28,883 | 411 | 175 | 130 | 716 | 1 | 6 | 58 | 65 | 1 | 3 |
| Southern Louisiana | 62,041 | 271 | 10 | 172 | 453 | 4 | 1 | 49 | 50 | 14 | 16 |
| Total | 90,924 | 682 | 185 | 302 | 1,169 | 5 | 7 | 107 | 115 | 15 | 19 |
| 1938: | | | | | | | | | | | |
| Northern Louisiana | [2] 28,443 | 350 | 117 | 140 | 607 | 1 | 1 | 47 | 49 | 1 | 3 |
| Southern Louisiana | [2] 66,731 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 19 | 24 |
| Total | [2] 95,174 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 20 | 27 |

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[1] Production figures from Bureau of Mines, except as noted; all other data from American Institute of Mining and Metallurgical Engineering, Petroleum Division.

[2] Preliminary figures, American Institute of Mining and Metallurgical Engineering, Petroleum Division Bureau of Mines preliminary figures for total Louisiana production are 94,812,000 barrels. Preliminary figures by districts are not available.

*Gulf coast.*—In the Louisiana Gulf coast district oil is obtained from structural traps formed by the intrusion of salt domes. At the end of 1938 there were 81 producing fields, as compared with 31 at the end of 1933. In addition to the producing fields there were known at the end of 1938 more than 100 other salt domes and salt-dome prospects in a coastal belt almost 100 miles wide that extends completely across the south edge of the State. Many of these prospects may ultimately become producing fields, but development of prospects into producing fields in the Louisiana Gulf coast is slow. This was strikingly illustrated by the discovery during 1938 of oil on the flanks of the Jefferson Island dome, one of the Five Islands—an alinement of topographically expressed domes known since the earliest period of oil exploration on the Gulf coast.

The accelerated tempo of oil-field discovery in this district during the last 5 years is to be attributed to the large number of prospects that had been indicated during preceding years by intensive geophysical exploration. The exploration of these prospects resulted in the emergence of southern Louisiana during the period 1934–38 as one of the outstanding deep-drilling regions of the world. The average depth at which oil was obtained from the new fields of 1937–38 exceeds 8,000 feet, as compared with about 6,500 feet for the new fields found in 1934–36. The high gas-oil ratio encountered in many of the new fields is a troublesome factor, but the deep drilling suggests that oil will probably be obtained from even greater depths than at present.

Despite the discovery of 50 new fields in the period 1934–38. 40 000,000 of the 66,000,000 barrels of oil produced during 1938 was obtained from the 31 fields existing at the end of 1933. These 31 fields have notably increased their production by the discovery and exploitation of new productive zones. For example, at the Jennings dome, the oldest Louisiana Gulf coast field, discovered in 1901. deep marginal development increased the production from 668,000 barrels in 1935 to 7,470,000 barrels in 1938. The successful search for new productive zones in old fields as well as for new fields has been enormously facilitated by the almost universal application of electrical logging. In all but 3 of the 19 new fields discovered in 1938 the discovery wells were completed by plugging back to sands previously drilled through.

Although production greatly increased during the 5-year period, the proved reserves were about doubled between January 1, 1935, and January 1, 1939, and are now estimated to be more than a billion barrels. Indeed, the probable reserves are even larger than that, because the reserves of the more than 30 new fields discovered in 1937 and 1938 cannot yet be properly evaluated, and they almost surely contain reserves that cannot yet be regarded as proved.

New structural features to be drilled will probably be found as geophysical prospecting is continued in the difficult swampy coastal terrain and in the coastal waters. Several of the producing fields lie in marine embayments. In 1938 the Creole field, in the Gulf of Mexico proper, 1 mile off the Cameron Parish shore, was discovered. However, no great expansion of the area that contains producing fields is anticipated. More likely is the discovery of oil in traps formed by less conspicuous structural features that will be detected by refinements in the technique of geophysical prospecting.

In considering the possibilities of production from ever deeper zones it is necessary to recognize that the producing sands of the Gulf coast region occur in a series of wedges, each of which is thick, is largely marine, and has only scattered potentially productive sands toward the coast. Northward toward the interior these wedges become thinner and nonmarine and normally contain no accumulations of oil and gas. From oldest to youngest these wedges or stratigraphic units are the Sparta-Wilcox, of Eocene age; the Cockfield-Yegua, Vicksburg, "Marginulina"-Frio, and the Miocene. Each successively younger wedge has a zone of greatest potential productivity that lies generally nearer the coast than that in the next underlying wedge. Thus, in the Sparta-Wilcox the potentially productive zone is farthest inland, whereas the comparable zone in the Miocene formations is close to the coast and, in part, under the coastal waters of the Gulf of Mexico. The landward margins of the potentially productive belt in each wedge have been delineated in part by drilling. The continued discovery of oil at greater depths is possible because the down-dip or coastward margins of the belts of potential production in all the wedges are still undefined, and consequently, so far as now known, productive sands may be found at great depths in the coastward phases of even the oldest wedges, although the sands may be thin and unsystematically distributed.

Although such very deep sands may ultimately furnish production, the known belts of greatest potential productivity or "trends" of each of the several wedges of Coastal Plain sediments are of more immediate interest, for their possibilities have not been exhausted, and they are being intensively prospected. Of special interest in the period under consideration is the discovery in 1937 of the Ville Platte field, in Evangeline Parish, where oil is obtained from the Sparta sand at a depth of about 9,000 feet—the first production from this formation on the Louisiana Gulf coast. In 1938 the Bancroft field, in Beauregard Parish, began to produce from the Cockfield or Yegua, and in January 1939 the Eola field, in Avoyelles Parish, developed substantial production from the Wilcox at 8,443–8,550 feet. It is to be expected that the discovery of these recent fields will lead to intensive search of the older inland "trends" which have not hitherto furnished production in the Louisiana Gulf coast.

Illustrative of several features of development in the Louisiana Gulf coast is the Tepetate field, which was discovered in July 1935 and which produced 5,619,852 barrels of oil to the end of 1938. The producing sand, encountered at an average depth of 8,300 feet, is in the lower "Marginulina" zone. Although the structure is due to a deep-seated salt dome, the structural trap is a low dome with 250 feet of closure at the producing level. Subsurface faults of considerable displacement downward to the south and southwest were found north and east of the field. The field was discovered solely by the application of geophysical methods and was first indicated by a reconnaissance torsion-balance survey in 1930.

*Northern Louisiana.*—The outstanding development of the 5-year period in northern Louisiana was the discovery during 1935 of productive oil sands in the Rodessa gas field, in the extreme northwest corner of the State, and in adjacent parts of Texas and Arkansas. The importance of this discovery may be gaged by the fact that in 1934 and 1935 northern Louisiana produced between 9,000,000 and 10,000,000 barrels, whereas the Louisiana part of the Rodessa field alone produced more than 19,000,000 barrels in 1936, more than 17,000,000 barrels in 1937, and more than 13,000,000 barrels in 1938. The oil produced in the Rodessa field comes from the lower Glen Rose and underlying Travis Peak formations, of the Trinity group, of Lower Cretaceous age.

In 1934 these deep zones were producing in northern Louisiana only from the Pine Island part of the Caddo field and Cotton Valley field and were the deepest producing zones, although a still lower formation of marine limestone, shale, and sandstone had been recognized. This lower formation, now called the Cotton Valley formation, has since been shown to be productive of oil and distillate in the Cotton Valley field and of distillate in the Shongaloo field. It has been tested in several fields and penetrated in the Rodessa field, where an underlying salt formation was encountered. The Buckner anhydrite, found below the Cotton Valley formation in Arkansas, and the still older Smackover limestone have not been conclusively shown to be present in Louisiana except in the northeastern part of the State. The salt encountered in the Rodessa field and in the Bethany gas field is, however, believed to be correlative with the salt of the Eagle Mills formation below the Smackover limestone in Arkansas. As a whole, the deep drilling in northern Louisiana during the period tended to decrease the possibilities for the very deep production from Mesozoic rocks below the Cotton Valley formation. In addition there has been accumulating evidence that the porosity in the deep sandstones and limestones now being tested is not persistently favorable for oil accumulation, a factor which will make future exploration somewhat more difficult. If accessible to drilling, the underlying Paleozoic rocks are presumably highly folded and perhaps metamorphosed and barren. Nevertheless, the outlook for new production in northern Louisiana is no more discouraging at present than in 1934 and 1935, prior to the discovery of the Rodessa and Lisbon fields. The increased production of northern Louisiana since 1935 has been obtained very largely from the lower Glen Rose or deeper zones, and future search apparently will be directed to the Glen Rose, Cotton Valley, and Smackover formations.

The date of discovery of Rodessa as an oil field is given as 1935, Sligo and Lisbon as 1936, Sugar Creek as 1937, and Shreveport (Cross Lake) as 1938. All of these except Lisbon had been previously known as gas fields.

The Lisbon field, in Claiborne and Lincoln Parishes, was discovered in December 1936. Within a year 163 producing wells had been drilled and had produced 2,440,640 barrels of oil. In January 1938, 4,100 acres had been proved with an estimated reserve of 10,500,000 barrels. At that time, however, the developments had not outlined the areal limits of the field except on the north side.

The field lies on a small anticline that plunges southwestward across the east flank of the broad north Louisiana syncline. However, the oil is obtained from the southeast flank of the small anticline and not from the high part of the fold. Oil is obtained from limestone in the lower Glen Rose (Lower Cretaceous) at an average depth of about 5,200 feet, and it is believed that the oil is trapped in lenticular zones of greater porosity in the producing limestone.

Several small gas and distillate fields have been discovered in the period. Among them are Simsboro in 1935, Sibley and Longwood in 1936, Bear Creek and Ruston in 1937, and Shongaloo and the Logansport extension in 1938. These are not listed as oil fields in table 17.

### MISSISSIPPI

As early as 1903 a test well for oil and gas was drilled to a depth of 1,842 feet in Clarke County, Miss., and since then more than 200 wells have been drilled in search for oil and gas in various parts of the State. The first well in Mississippi to yield oil was in sec. 13, T. 5 N., R. 1 E., on the Jackson anticline, in Rankin County. This well was drilled to a depth of 3,607 feet in 1930, but was plugged back to about 2,500 feet. It produced gas and some oil from the Selma chalk, of Upper Cretaceous age. Since then gas has been produced from more than 100 wells in the Jackson field, which is located on a dome in the rocks above an igneous plug. Three wells on the southeastern edge of the Jackson gas field have produced some heavy oil with salt water. Their aggregate oil production for the period 1935–37 was reported as 2,425 barrels, and their total production to June 1937 was about 15,000 barrels.

In the first week of September 1939 asphaltic oil of 34.2° gravity was discovered in a well in section 13, T. 10 N., R. 3 W., about 10 miles south of Yazoo City, in Yazoo County, on the Tinsley dome. The well went to a depth of 4,560 feet and, on September 11, 1939, it was reported to be producing 93 barrels of oil in 12 hours from a sand of Upper Cretaceous age. The Tinsley dome and the Satartia dome, about 5 miles southwest of the Tinsley dome, were discovered through geologic studies checked by seismograph surveys. Several local domes or flexures have been detected in Warren County, including the Glass dome, about 7½ miles southwest of Vicksburg, and the Blakely fold, about 7 miles northeast of Vicksburg.

The first salt dome discovered in the State is the Scanlan or Midway dome, in sec. 28, T. 4 N., R. 15 W., Lamar County, where a well drilled to 4,024 feet and abandoned found salt at 2,522 feet. Several other wells have since been drilled here, one to a depth of 8,673 feet. Other salt domes have since been discovered at Edwards and at least one other locality in Hinds County.

In the last year or two geophysical surveys have been made, especially in the southern part of Mississippi along the extension of the so-called "Sparta-Wilcox" trend. It is in this trend that oil production has been developed at the Ville Platte, Eola, and Bancroft fields in Louisiana and other fields in Texas. It seems possible that oil may be found in southern Mississippi in Cretaceous or Tertiary formations if suitable traps can be detected and adequately tested by the drill.

### MISSOURI

Small amounts of oil have been produced in Missouri for several years from shallow formations in the Pennsylvanian series in several western border counties, notably Cass, Jackson, Vernon, Platte, and Clinton Counties.

Prior to the end of 1932 there had been 320 small shallow oil wells completed in Missouri, more than half of them in the Richards-Stotesbury area of Vernon County. In 1933 and 1934, 10 oil wells were completed with an aggregate initial daily capacity of 100 barrels. The principal development was an extension of the Knoche pool, in Cass County, where seven wells were drilled to a depth of 600 feet and obtained oil from the Squirrel sand, in the Cherokee shale. The largest well pumped 25 barrels daily after being shot. This field is on a small anticline.

During 1933–34 there were eight producing oil wells in Cass County and two in Platte County, with a total daily production of 100 barrels.

In 1935 drilling for oil in Missouri was confined largely to proved areas. One of the largest oil wells in the State was completed in Platte County (T. 50 N., R. 33 W.). This well flowed 53 barrels daily.

During the period 1935–36, 35 oil wells were completed, including the deepening of 3 old wells. The total initial flush production was about 211 barrels of oil a day, but the wells soon settled to a daily yield ranging from 1 to 3 barrels of oil each; 16 of the wells were in Cass County, 17 in Jackson County, and 2 in Platte County.

Two small oil pools were developed in Cass County in 1936, and additional wells were drilled in the vicinity of Martin City in Jackson County and in the Knoche pool. In section 7, T. 50 N., R. 33 W., Platte County, oil was found in two wells in a new zone, a sand below the Lexington shale which may be the equivalent of the Wheeler sand in Oklahoma. One of the wells yielded on pumping 4½ barrels a day on a 30-day test.

In 1937, 8 oil wells (including 1 old well drilled deeper) were completed in previously discovered pools in Jackson and Cass Counties. The aggregate initial daily capacity was 125 barrels.

During 1938 there was active interest and leasing in that part of the Forest City basin that lies in northwestern Missouri. It is possible that a number of formations in which oil has been found in Illinois and Kansas underlie the Forest City basin, and there has been an active campaign of leasing and some drilling in the area. The Nemo uplift and the Lincoln fold, in northeastern Missouri, have also been receiving the attention of oil men, as well as the western border counties of Vernon, Bates, and Henry. Late in the year two oil wells were completed in the vicinity of Richards, in Vernon County, yielding 5 and 3 barrels of oil daily at depths of 250 and 170 feet, respectively; the first produces oil from the Burgess sand and the second from the Bartlesville sand. Another well near Richards found oil in the Bartlesville at a depth of 109 feet and had an initial production of 30 barrels in 24 hours.

A summary given by the State geologist indicates that for the period 1937–38 drilling in Missouri resulted in the addition of 23 new oil wells with a total initial daily production of 242 barrels.

A few wells have been drilled in the southeastern lowlands of the State, and it is possible that further attention will be given to oil possibilities there, in view of the interest in the adjacent parts of western Tennessee and northeastern Arkansas, where Paleozoic formations underlie the Cretaceous and Tertiary.

### NEW MEXICO

Throughout the period 1934–38 New Mexico held its rank as sixth among the oil-producing States. Its entire output came from Lea and Eddy Counties, in the southeast corner of the State, and San Juan County, in the northwest corner. Its total yearly production increased steadily from 14,000,000 barrels in 1933 to a peak of more than 38,000,000 barrels in 1937 but dropped to a little less than 36,000,000 barrels in 1938. Its known reserves increased during the 5-year period from 92,500,000 barrels at the end of 1933 to 703,000,000 barrels at the end of 1938. This tremendous gain was due to continued discoveries and development of the fields of the Permian basin in Lea and Eddy Counties.

New Mexico first produced oil in important commercial amounts in 1923, when the Hogback field, San Juan County, was developed. The State's output was more than 1,000,000 barrels in 1925, following the development of the Artesia field, in Eddy County; and its production jumped to 10,000,000 barrels in 1930, when new fields were developed rapidly in Lea County. Four fields in Lea County have accounted for three-quarters of New Mexico's total output of 198,000,000 barrels of oil to the end of 1938—Hobbs, 85,000,000 barrels; Eunice, 32,000,000 barrels; Monument, 24,000,000 barrels; and Cooper, 9,000,000 barrels. The Artesia field had a total production to the end of 1938 of 11,000,000 barrels.

By far the greatest amount of drilling activity in New Mexico during the period 1934–38 took place in Eddy and Lea Counties, resulting in the discovery of a few new fields and the extension of many of the old ones. Drilling activity is summarized in the following table:

TABLE 18.—*Wells drilled in southeastern New Mexico, 1934–38*

| Year | Wells drilled | Oil wells | Gas wells | Wildcat wells | Wildcat wells finding oil or gas |
|---|---|---|---|---|---|
| 1934 | [1] 144 | [1] 107 | [1] 13 | ------ | ---------- |
| 1935 | [1] 337 | [1] 262 | [1] 4 | 32 | 4 |
| 1936 | 547 | 516 | 7 | 19 | 7 |
| 1937 | 666 | 603 | 20 | 40 | 3 |
| 1938 | 559 | 489 | 17 | 33 | 4 |

[1] Figures are for the entire State, but most of the wells were in the southeastern part.

Oil in southeastern New Mexico occurs in much the same manner as it does in the adjacent western Texas area, but all the producing zones are in rocks of Permian age. There are three main types of occurrence:

1. In the top of the Delaware sand (upper Permian) in the Delaware Basin. This is a deep structural depression in southern Lea and Eddy Counties.
2. In limestones of middle to upper Permian age north and east of the Delaware Basin, the youngest producing zones being nearest the basin.
3. In sandstones of middle to upper Permian age north and east of the Delaware Basin, the youngest producing zones being nearest the basin.

In contrast to western Texas, no production is known to have been obtained from the Ordovician or Pennsylvanian, and little or no exploration is being done for oil in these beds.

The main producing areas of southeastern New Mexico follow two broad trends, which bend about in semicircles parallel to the edge of the Delaware Basin from southeastern Lea County northwestward into eastern Eddy County. Along the southern trend oil is obtained from upper Permian limestones and sandstones; along the northern trend from the middle Permian. During the period discussed exploration was active along both trends, as well as in the intervening area, and some wildcat wells were put down north of the northern trend.

Most of the major discoveries during the period were along the southern trend, especially in southern Lea County. Here several outstanding fields were discovered, including the Cooper (1934) and the Monument (1935). An older field, the Empire, was revived by the discovery in 1938 of large yields near some of the existing wells. In addition, several small fields near and between the larger ones were found.

A great deal of exploration has also been done along the northern trend and in nearby areas. During 1937 and 1938 small quantities of oil were found at several places in Eddy and Lea Counties southeast of the old Artesia field. This oil appears to come from sands pinching out northward against the fold that forms the northern trend. Considerable exploration is taking place here, and there appear to be possibilities of small production of this sort at many places. The most important discovery in the northern trend, however, was that of a field near Lovington in 1938, but so far its production has been small. The oil comes from middle Permian limestones.

Considerable exploration is now taking place north of Lovington to test the possibilities of the same limestone zone, but so far without results. Oil may be found here, but the limestone tends to disappear in this direction by interfingering with anhydrite and red beds. It seems likely that important production will not be obtained unless some lower zone is discovered, but several deep tests have failed to discover such a zone. One of the outstanding tests was the Shell Oil Co.'s Harwood No. 1, north of Lovington, near the south edge of Roosevelt County. It reached a depth of nearly 10,000 feet early in 1939 before being abandoned.

In addition to the occurrences already described, exploration during the period suggested that some oil might be obtained from the Delaware sand of the New Mexico part of the Delaware Basin. A few small fields are producing from this zone in Texas. In 1937 oil was found in the Delaware sand southwest of Carlsbad, where it lies at shallow depth. Farther east, however, many wildcat wells have been put down in the Delaware Basin without finding oil. Any further discoveries will probably be small.

One of the outstanding fields discovered in the 5-year period following 1933 is the Monument field, in east-central Lea County, between the Hobbs and Eunice fields. The field lies on a broad anticlinal fold, in contrast to the rather narrow anticlines in the more southerly fields. Oil is obtained from porous dolomitic middle Permian limestone at an average depth of 3,950 feet. The oil is in a horizontal zone about 150 feet thick overlying a water table, but the productive limit of the fold is defined by the absence of porosity in the reservoir rock. The field was discovered in 1935, and by the 1st of July 1938, 473 wells had been drilled and had produced a total of 19,750,000 barrels of oil.

In New Mexico, as in western Texas, most of the exploration for oil is done with the aid of geologic and geophysical methods. Structural and stratigraphic relations are determined by study of wells that have already been drilled. Geophysical work is done either as pure exploration for structurally high areas in districts that have not been drilled, or as a means of defining structural features in areas in which some drilling has been done.

About 100 wells were drilled in northern New Mexico in 1934–38, all but a very few of them in the northwestern part of the State. Most of the wells were drilled to develop more fully the known fields of San Juan County that produce from the Dakota (?) sandstone, of Cretaceous age, particularly the Rattlesnake, Hogback, and Table Mesa fields. These fields were, however, not materially extended by the drilling. The Rattlesnake field has produced oil of extraordinarily high gravity, as high as 76°, American Petroleum Institute.

In 1937 northwestern New Mexico produced 387,323 barrels of oil, and in 1938 the production was 357,977 barrels. The proved reserves January 1, 1939, are estimated at 5,056,000 barrels.

Oil possibilities in the Cretaceous formations in the southern San Juan Basin were further explored, and one small additional field was discovered at Red Mountain in 1936, oil being obtained from a small faulted anticline in the Mesaverde formation (Cretaceous) at a depth of 440 feet. The oil has a gravity of 42°, American Petroleum Institute. About 25 wells were drilled in this field, and 6 of them produced oil in 1936 and 1937. The drilling proved that the field is small and holds no considerable reserve. The production in 1936 was reported as 1,600 barrels and the production in 1937 as 1,200 barrels.

The Cretaceous formations of the San Juan Basin have not yet been fully explored, but drilling thus far would indicate that only small additional fields will be found. The petroleum possibilities of the deeply buried Pennsylvanian rocks in the basin are difficult to evaluate. Oil of 40° gravity has been obtained from Pennsylvanian strata in the Rattlesnake field, but these strata have been adequately tested at but few places elsewhere in the basin.

### OKLAHOMA

Nearly a billion barrels of oil was produced in Oklahoma from 1934 to 1938. The amount produced annually increased each year through 1937 and decreased abruptly in 1938; in fact, the amount produced in 1938 was the least of any year in the 5-year period. The total annual production is shown by years in the following table. The sharp decline in production in 1938 is noteworthy.

TABLE 19.—*Reserves and annual production of oil in Oklahoma, 1934–38, in barrels*

| Year | Proved reserves at beginning of year | Production during year [1] | Year | Proved reserves at beginning of year | Production during year |
|---|---|---|---|---|---|
| 1934 | [2] 1, 503, 430. 000 | 180, 107, 000 | 1938 | [3] 1, 310, 652, 000 | 174, 882, 000 |
| 1935 | [2] 1, 480, 000, 000 | 185, 288, 000 | 1939 | [3] 1. 162, 370, 000 | |
| 1936 | [2] 1, 498, 890, 000 | 206, 555, 000 | | | |
| 1937 | [3] 1, 383, 464, 000 | 228, 839, 000 | Total | | 975, 671, 000 |

[1] Bureau of Mines.
[2] Sources believed to be reliable.
[3] American Petroleum Institute.

A fourth (259,000,000 barrels) of the State's total yield during the 5-year period came from the Oklahoma City field, whose annual yield was maintained above 50,000,000 barrels until 1938, when it fell to 38,796,000 barrels. The Fitts field, which ranked second, produced a total of 74,800,000 barrels in the 5-year period. The St. Louis field, which ranked third, produced a total of 39,125,000 barrels. It is noteworthy that these three leading oil fields are widely separated, but most of the oil in each field was derived from the Wilcox sand and other sands in the prolific Simpson group of Ordovician age.

*Reserves.*—As shown in table 19, the estimated proved reserves of oil in Oklahoma have been reduced each year throughout the 5-year period 1934–38, except for a slight increase in 1936. Although nearly a billion barrels was produced during the period, only a little more than half that amount was discovered.

*Oil wells, gas wells, and dry holes.*—The following table shows the number of oil and gas wells and dry holes drilled in Oklahoma in the 5-year period.

TABLE 20.—*Wells drilled in Oklahoma, 1934–38* [1]

| Year | Oil wells | Gas wells | Dry holes | Total |
|---|---|---|---|---|
| 1934 | 1,161 | 91 | 465 | 1,717 |
| 1935 | 1,321 | 110 | 579 | 2,010 |
| 1936 | 1,790 | 126 | 649 | 2,565 |
| 1937 | 1,852 | 123 | 697 | 2,672 |
| 1938 | 986 | 160 | 545 | 1,691 |
| Total | 7,110 | 610 | 2,935 | 10,655 |

[1] Statistics from Bureau of Mines.

Activity in drilling wells, particularly wildcats, in Oklahoma increased greatly in 1934 over 1933 and continued to increase each year through 1937. In 1938, however, drilling was sharply curtailed, mainly because new fields in Oklahoma were not needed, but in part because of the lack of success of many wildcat wells that had been drilled in promising localities. Many major operators of Oklahoma had transferred their interests and exploration funds to further the rapid development in Illinois, where, owing to shallow drilling, liberal allowables for production, and good prices for crude petroleum, quick returns were realized on capital invested.

*Discoveries and developments.*—From 30 to 45 new oil pools were discovered in Oklahoma each year from 1934 to 1938, but only a very few added large reserves to the State. Many of the new pools really represented extensions to old producing areas; others, whose importance is large, represented new producing zones in old pools.

Oil occurs in Oklahoma under greatly diversified conditions of structure and stratigraphy. In a roughly circular area having a radius of about 70 miles and centering at Tulsa, in northeastern Oklahoma, oil is found in hundreds of fields in stratigraphic and structural traps in Pennsylvanian strata and in a much smaller number of fields in structural traps in Mississippian and Ordovician strata. Farther west, in north-central Oklahoma, oil is produced from Pennsylvanian and Ordovician strata in many anticlines that lie in a narrow belt extending southward from the Kansas State line to Oklahoma City. Most of the anticlines are elongated asymmetric folds arranged en echelon above a buried granite ridge that is the continuation of the buried granite ridge of Kansas. In central Oklahoma oil is produced from Pennsylvanian, Silurian, Devonian, and Ordovician strata in numerous large and small fields situated on irregular domes and anticlines superimposed on the roughly circular Seminole uplift, which is about 40 miles in diameter.

Southeast of that area lies the Fitts field, which is described separately below. In the southwestern part of the State several fields lie in a belt that trends west-northwestward from Ardmore. In the eastern part of that belt oil is obtained from Pennsylvanian and Ordovician strata on steeply folded elongate anticlines, and in the western part from gently folded Permian strata and more steeply folded Pennsylvanian beds. Small amounts of oil have also been found in scattered areas in the State—from open reservoirs in Pennsylvanian sands in the Ouachita Mountains, from shallow Cretaceous sands on anticlines in the Coastal Plain in Marshall County, and from Pennsylvanian and Permian sands in anticlines on the north flank of the buried Wichita-Amarillo Mountains.

Probably 50 percent of the new discoveries in Oklahoma during the period following 1933 were guided by geophysical (mainly seismograph) surveys, most of which were directed and interpreted by geologists in conjunction with subsurface or surface geologic mapping. All discoveries that added large reserves, however, were based entirely on surface or subsurface geologic investigation. A few small discoveries were made by wildcatting without geologic or geophysical guidance.

Important discoveries in 1934 were (1) the large production of oil from the Bromide formation in the Fitts field, where some oil had been found at shallower depths in 1933; (2) the south Burbank field, and (3) the Olympic field. Lesser finds were the Polo, Langston, Wilzetta, Gessman, Shawnee, and Dill pools. New development was carried on in the greater Seminole district, particularly in the St. Louis field. The Lucien, Crescent, and Edmond pools were developed. Experimental water-flooding and gas-repressuring of the reservoir sands were carried on in old shallow fields in northeastern Oklahoma.

In 1935 the Wilcox sand was found productive in the Fitts pool; development of the prolific Simpson sands was extended in the Capitol area of the Oklahoma City field; and large yields, which later proved disappointing, were found in the Simpson group in the old Fox pool, in Carter County. The Stillwater, Jesse, Britton, South Keokuk, Wofford, Grayson, and Hoyt pools were discovered. The Fitts, Edmond, and Olympic pools were extensively developed. Water-flooding and gas-repressuring operations were extended in shallow sands in the northeastern part of the State. A unit operating plan in the greater part of the south Burbank field provided for the maintenance of high pressure in the reservoir sand by the return to it of the casing-head gas.

The Moore oil pool, in the Wilcox sand, was found in 1936. Oil was found in the Wilcox sand in the old Billings pool; the north Bethel, north Earlsboro, and north Lucien pools were discovered. The Fitts pool, the Capitol area in the Oklahoma City field, the Olympic pool, and the Edmond, Jesse, Keokuk Falls, and south Burbank fields were rapidly developed. Much attention was given to the drilling of wells for the disposal of salt water.

The Ramsey pool, in the Wilcox sand, was the outstanding discovery in 1937. Other discoveries were south Cromwell, Langston, and north Langston. The deep drilling in the Fox-Millroy area continued; the Cromwell and Gilcrease sands, in the Fitts pool, and the Moore and Jesse pools were developed.

The Ramsey pool was the outstanding development in 1938; activity was also pronounced in the greater Seminole area, particularly in the St. Louis field. The old Cement field was extended westward.

*Areas of active interest and possibilities for new fields.*—Stimulated by the finding of oil in the Fitts pool, leasing and geologic investigation were active in the early part of the 5-year period in the McAlester Basin and the Ouachita Mountains, in southeastern Oklahoma. Interest in this area is now greatly diminished because of the failure of several wildcat holes. Interest was shown for a time in the area south of the Wichita Mountains in southwestern Oklahoma, because of the finding of oil in the Pennsylvanian and Ordovician rocks near Altus, but drilling disclosed that the Simpson sands are thin or absent in much of that region.

Leasing and subsurface and surface geologic investigation followed by geophysical investigation have been and are still being carried on along the south flank of the Anadarko Basin, including Caddo, Kiowa, Wachita, Beckham, Custer, and Roger Mills Counties. The main objectives are the sands of the Simpson group. Similar activity is in progress in a broad belt that lies immediately west of the Nemaha granite ridge pools and includes Canadian, Blaine, Kingfisher, Major, Garfield, Grant, Alfalfa, and Woods Counties.

Both of these large areas, which include much of central and western Oklahoma, are looked upon with favor as a region for prospecting because they are underlain by essentially all the zones, particularly the sands of the Simpson group and the Arbuckle limestone, that have produced most of the oil in Oklahoma. Also several wildcat wells have obtained large shows of oil and gas. The anticlines are difficult to detect, however, because of a scarcity of mappable key beds in the exposed rocks. The prospector must rely upon subsurface mapping, core drilling, seismograph investigations, and other methods, including those used in locating stratigraphic traps. The prospective oil sands lie at greater depth here than in eastern Oklahoma and, therefore, exploratory wells are much more costly. Development in this part of the State has been retarded because of the failure of several wildcats and mainly because of the competition from shallow-oil districts such as Illinois, but at some time in the future this area will doubtless be intensively explored.

Large parts of Stephens, Grady, Cleveland, Garvin, Pottawatomie, Lincoln, and Logan Counties are under lease; new pools are expected northwest of the Carter and Stephens Counties' fields and along the southeastward extension of the Oklahoma City-Moore trend. More fields like the Ramsey field may be found in a broad belt in central and north-central Oklahoma, east of the Nemaha granite ridge fields, where many companies hold leases. Successful exploration will continue in the greater Seminole district and in the belt that extends from it northward to Cushing. This belt contains the thick oil-bearing sands of the Simpson group, the important Viola and Hunton limes, and rich oil-bearing sands in the Pennsylvanian series. Additional sand-lens pools of the south Burbank and Olympic type should be found in southwestern Osage, Pawnee, Creek, Okfuskee, Hughes, and Seminole Counties. The practice of repressuring old pools, particularly those in Pennsylvanian sands, with gas or water, will continue and eventually, over a long period of years, will recover considerable oil.

*Examples of the new oil pools.*—South Burbank pool: The south Burbank pool, in Tps. 25 and 26 N., R. 6 E., western Osage County, was discovered January 5, 1934, by projecting the general trend of the old Burbank pool. The oil, which is of 38° gravity, occurs in the Burbank sand of the Pennsylvanian series at a depth of about 2,850 feet. The pool comprises about 4,700 acres, more than half of which is operated as a single unit. The casing-head gas in almost the whole field is returned to the reservoir sand for the purpose of maintaining the reservoir pressure at a slowly declining rate from the original pressure, which was about 1,100 pounds. The plan has been highly successful. At the end of 1938 a total of about 21,000,000 barrels of oil had been produced from the pool, and the reservoir pressure was still more than 600 pounds.

The reservoir sand at South Burbank is an elongated bar-shaped lens that is about 7 miles long and 1½ miles wide. The sand attains a maximum thickness of 100 feet in the middle of the field but thins abruptly laterally and pinches out on the margins of the field. The strata in the field dip westward at a fairly uniform rate of about 40 feet to the mile. The accumulation of oil is controlled by the pinching out of the reservoir sand rather than by the attitude of the rocks.

Moore pool: The Moore pool, in T. 10 N., R. 2 W., Cleveland County, about 3 miles southeast of the Oklahoma City field, was discovered as a gas pool in June 1935, but in April 1936 oil was discovered in large volume in the second Wilcox sand, below the gas zone. In contrast to the pressure-maintenance practice of the South Burbank field, great quantities of gas were allowed to flow freely from wells near the crest of the Moore anticline; this wasteful practice depleted the natural reservoir pressure, and as a result the wells soon produced large quantities of water. By the end of 1938 the proved area included about 1,000 acres; the field had produced a total of 6,186,385 barrels of oil, of which 1,753,035 barrels was produced in 1938; a large volume of water was being handled.

The Moore pool is on an anticline that is one of a long chain of sharply folded anticlines, many of which are faulted. This chain overlies the buried Nemaha granite ridge, which extends in general northward through north-central Oklahoma, across Kansas, and into Nebraska. This chain of anticlines includes, among others, the Oklahoma City, Garber, and Blackwell fields in Oklahoma, and the Oxford, Augusta, and El Dorado fields in Kansas. Only a slight reflection of the anticline at Moore is evident in the exposed rocks, but the fold in the buried rocks is pronounced. Like most granite-ridge folds, the beds dip steeply on the northeast flank and dip gently on the southwest flank.

Fitts field: The Fitts field, in T. 2 N., Rs. 6 and 7 E., Pontotoc County, was discovered in July 1933, when oil was obtained from the Chimneyhill limestone (Silurian) of the Hunton group. It was recognized as an important field in June 1934, when a production of 300 barrels a day was obtained from the Bromide formation of the Simpson group (Ordovician). Gas-oil ratios in the Ordovician producing zones are low, 360 to 700 cubic feet to the barrel, which indicates the absence of a gas cap in those zones and has resulted in a relatively slow decline of pressure. Both pressures and gas-oil ratios, however, are variable in the Hunton group, where there is evidence of a gas cap. At the end of 1938 the field was well defined, had an area of about 5,450 acres, and had produced a total of 74,800,000 barrels of oil, of which 16,700,000 barrels was produced in 1938.

The Fitts field is on an anticline situated in a graben between two faults that converge westward. The anticline trends east-west and is asymmetric, with the steeper dips on the south flank. The south boundary of the field is essentially outlined by a southward-dipping normal fault that splits into several parts both along the strike and upward. Oil is obtained from shallow sands in the McAlester and Atoka formations (Pennsylvanian); the Cromwell sand (Pennsylvanian); the Hunton group (Silurian and Devonian); and the Viola limestone and seven zones in the Simpson group (Ordovician). The greatest part of the oil produced comes from the Simpson group, but production from the overlying limestones of the Viola and Hunton is also important.

## TEXAS

During the 5-year period, 1934–38, Texas produced 2,187,525,000 barrels of oil, or 39.8 percent of the total produced in the United States during the same period. In that period the proved oil reserves in Texas increased from a little less than

6,000,000,000 to more than 9,000,000,000 barrels, more than half of the proved oil reserves of the entire country. About half of the new oil wells completed in the United States during the period were in Texas. The accompanying table shows some of the significant data pertaining to oil production in Texas during the years 1934 to 1938. Oil production in Texas reached a peak in 1937 and fell off somewhat in 1938, owing largely to the generally lower price of crude oil and to lessened industrial activity.

TABLE 21.—*Wells drilled, annual production, and oil reserves in Texas, 1934–38*

| Year | Wells drilled | Oil wells | Dry holes | Production (barrels) | Reserves (barrels) |
|---|---|---|---|---|---|
| 1934 | 9, 912 | 7, 307 | 2, 337 | 381, 516, 000 | 5, 884, 000, 000 |
| 1935 | 11, 525 | 8, 506 | 2, 756 | 392, 666, 000 | 6, 643, 000, 000 |
| 1936 | 12, 297 | 9, 300 | 2, 650 | 427, 411, 000 | 8, 343, 114, 000 |
| 1937 | 14, 997 | 11, 529 | 3, 012 | 510, 318, 000 | 9, 691, 449, 000 |
| 1938 | 12, 184 | 9, 149 | 2, 666 | 475, 614, 000 | 9, 447, 764, 000 |
| Total | 60, 915 | 45, 791 | 13, 421 | 2, 187, 525, 000 | ------------ |

Texas contains six rather clearly defined oil-producing provinces or districts. The recent oil developments of the State are, for convenience, discussed by districts. In the accompanying table is shown the relative magnitude of each district in terms of percentage of the State's total oil production for the years 1934 to 1938.

TABLE 22.—*Percentage of annual oil production in Texas, 1934–38, by districts*

| District | 1934 | 1935 | 1936 | 1937 | 1938 |
|---|---|---|---|---|---|
| Panhandle | 5. 3 | 5. 4 | 5. 2 | 5. 4 | 5. 0 |
| North- and west-central Texas | 8. 5 | 7. 9 | 7. 7 | 7. 3 | 7. 9 |
| West Texas | 13. 1 | 14. 1 | 14. 4 | 14. 8 | 15. 3 |
| East Texas | 62. 6 | 49. 6 | 44. 3 | 41. 4 | 38. 8 |
| Gulf coast | 14. 1 | 14. 4 | 16. 2 | 16. 4 | 15. 6 |
| South Texas | 7. 4 | 8. 6 | 12. 2 | 14. 7 | 17. 4 |

This table shows vividly the declining prominence of the east Texas district despite the fact that even in 1938 east Texas produced more than twice as much oil as any other district in the State. The table also shows the steady gains that the south Texas district made during the 5-year period. In the south Texas district, the discovery and development of new fields has been exceptionally rapid and, in contrast to the rest of Texas, the oil production in 1938 exceeded that of 1937 by a considerable margin.

*Panhandle.*—The Panhandle oil fields were discovered in 1922. The oil is produced from the Wichita group (Permian) and the Cisco group (Pennsylvanian). The lower part of the Cisco consists largely of arkose or "granite wash."

The dominant structural feature of the district is a large anticline, the Amarillo uplift, that extends northwestward across the greater part of the Panhandle. Beneath this anticline is a deeply buried ridge of granite. Oil is trapped chiefly on the north flank of this anticline in minor folds and in lenses of arkosic sand derived from the granite ridge in Pennsylvanian or pre-Pennsylvanian time. The oil occupies porous beds that contain water down the dip and a vast body of natural gas up the dip. The average depth of the producing wells is close to 3,000 feet.

A few small oil pools have been found near the northwest end of the Amarillo uplift and also on the south flank, but they are insignificant compared with the large cluster of closely spaced pools on the north flank.

During the period 1934–38 the principal development in the Panhandle has been the extension of already known pools. The completion of new oil wells and the production of the district for each of the 5 years is shown in the accompanying table.

TABLE 23.—*Oil wells completed and annual oil production of the Panhandle district, Texas, 1934–38*

| Year | New oil wells completed | Production of district (barrels) | Year | New oil wells completed | Production of district (barrels) |
|---|---|---|---|---|---|
| 1934 | 375 | 20, 280, 000 | 1937 | 655 | 27, 617, 000 |
| 1935 | 549 | 21, 369, 000 | 1938 | 445 | 23, 556, 000 |
| 1936 | 475 | 22, 357, 000 | | | |

The development of the Panhandle oil fields during 1934–37 continued at about the same gradual rate that it did between discovery and the end of 1933. The decline in both production and number of oil wells completed in 1938 was marked. Most of the extensions of known fields have resulted from exploratory drilling, but new spots of production and some of the extensions of pools have been located by a combination of magnetometer surveys and exploratory drilling.

It is expected that comparatively few more oil pools at the depths of those now producing will be found, but the present pools may be enlarged somewhat. The oil possibilities of stratigraphic and structural traps in the pre-Pennsylvanian formations are essentially unexplored. Wells 5,000 to 8,000 feet deep will be required to test such traps, after both subsurface geology and geophysical methods have cooperated to locate the most promising sites.

*North-central and west-central Texas.*—In north-central and west-central Texas oil is produced principally from the Strawn and Bend groups (Pennsylvanian), which are separated by an unconformity. Locally, oil is obtained from the much older Ellenburger limestone (Cambrian and Ordovician), and in 1938 oil in commercial quantities was discovered in the Mississippian beds between the Bend group and the Ellenburger limestone.

Production throughout the area is controlled by both structural and stratigraphic traps. The dominant structural feature is the Bend arch, which extends northward from the domal uplift of the Central Mineral region, in Llano and adjacent counties. Upon the Bend arch are superposed two sets of smaller anticlines—an older set that trends north and northeastward and a younger set that trends northwestward. Subsurface faults extending northward from the much-faulted Central Mineral region and displacing the formations on the flanks of the Bend arch may have aided in the formation of structural traps not yet fully explored. North of the Bend arch is the Red River uplift, which extends westward through Clay, Wichita, and Wilbarger Counties. Numerous producing fields, generally similar to those on the Bend arch, are located on the Red River uplift.

In each of the 4 years 1934–37 north-central and west-central Texas together reported the completion of about the same number of oil wells (1,316 to 1,403), but in 1938, owing largely to the development of the deep sand in the K. M. A. field, the number of completed oil wells rose to 1,774. The distribution of the number of completed oil wells by years and the oil production of these two districts by years is given in the accompanying table.

TABLE 24.—*Oil wells completed and annual oil production in the north- and west-central Texas districts, 1934–38*

| Year | Oil wells completed | Production (barrels) | Year | Oil wells completed | Production (barrels) |
|---|---|---|---|---|---|
| 1934 | 1, 325 | 31, 588, 000 | 1937 | 1, 402 | 37, 580, 000 |
| 1935 | 1, 316 | 31, 098, 000 | 1938 | 1, 774 | 37, 353, 000 |
| 1936 | 1, 403 | 33, 041, 000 | | | |

In the 5 years 1934–38 new oil pools were discovered at an increasing rate, despite the fact that these are old districts that have long produced oil. The discoveries ranged from 3 in 1934 to 26 in 1937 and totaled 67. In the same period one or more new producing zones were discovered at greater depths in many old fields, amounting to a total of 30 new producing zones in these two districts. Many of the new deep pools lie below old producing pools, but the development of the deep pools has enlarged the area of many of the fields. New pools were also found in already known sands but in areas heretofore not tested. The producing wells range from 150 to 4,000 feet in depth, and the new producing zones from 3,000 to 4,000 feet.

Most of the new fields owe their discovery to deeper drilling and their effective completion to slight penetration of the producing zones and to casing perforation at parts of each productive zone determined by electrical logging.

The outstanding development in these districts is the deep production in the K. M. A. field, in southwestern Wichita County. Oil had been produced there from the upper Pennsylvanian rocks in wells from 400 to 1,700 feet deep as early as 1919, and in 1931 additional drilling proved the presence of oil at greater depths. However, subsequent tests were disappointing, and in 1935 only five wells were producing from the deeper strata. In 1937 electrical logging and perforation of casing in only oil-bearing zones led to greater success, and in 1938 the number of producing wells increased from 89 to 890. The field has now proved about 50,000 acres and at the beginning of 1938 had a reserve estimated at 400,000,000 barrels of oil.

The oil is produced from northwestward-trending anticlinal folds in beds believed to be of Strawn (Pennsylvanian) age. Several beds of sandstone and limestone in a zone about 300 feet thick have been found to be productive. These beds lie at depths of 3,500 to 4,000 feet. They rest uncomformably on older beds that are also folded, but the folds in these older beds trend generally northeastward. A few wells have been drilled into the older beds without encountering production but not enough deep wells have yet been drilled to locate the anticlines in the underlying discordant set of folds and so test the oil possibilities of the older formations.

It is to be expected that a large number of wells will continue to be drilled in north- and west-central Texas, because the producing zones lie at comparatively shallow depths, and at the end of 1938 the possibilities of new discoveries appeared to be good. Many of the northeastward-trending folds in the Pennsylvanian Bend group and still older formations are as yet inadequately tested.

*West Texas.*—During the period 1934–38 many new oil fields were discovered in west Texas. As in many other districts in Texas the number of oil wells completed and the production increased steadily from 1934 to a peak in 1937 and then fell off somewhat in 1938. The data for production and oil wells completed are given in the accompanying table.

TABLE 25.—*Wells drilled, oil wells completed, and annual oil production in the west Texas district, 1934–38*

| Year | Wells drilled | Oil wells completed | Production (barrels) |
|---|---|---|---|
| 1934 | 583 | 461 | 50, 272, 000 |
| 1935 | 813 | 636 | 55, 417, 000 |
| 1936 | 1, 579 | 1, 350 | 62, 039, 000 |
| 1937 | 2, 898 | 2, 525 | 75, 743, 000 |
| 1938 | 2, 290 | 1, 921 | 72, 653, 000 |

Oil in this district is derived from four different sources:

1. From the top of the Delaware sand (upper Permian) in the Delaware Basin, a deep structural depression in Culberson, Reeves, and Loving Counties and western Ward and Pecos Counties.
2. From limestone beds of middle to upper Permian age east and north of the Delaware Basin, the youngest producing zones being nearest the basin.
3. From sandstones of middle to upper Permian age east and north of the Delaware Basin, the youngest producing zones being nearest the basin.
4. From the Simpson formation and underlying beds of Ordovician age which lie unconformably below the Permian.

Production from the first three sources is determined partly by stratigraphic factors, such as lensing of sands and changes in porosity in limestone, and partly by structural factors, such as the crossing of low anticline folds over the stratigraphic traps. Production from the fourth source is determined partly by structure and partly by truncation of the Ordovician structural features by the overlying Permian formation. In addition to the sources of production mentioned, some wells along the east edge of the area produce from the Pennsylvanian rocks.

New production in the west Texas district during the period came from all four sources. A large number of the new fields discovered were in the already prolific producing area of Winkler, Ector, Ward, Crane, and Upton Counties and were near or between fields already proved. This area is a broad, structurally high district known as the Central Basin platform, which lies east of the Delaware Basin. Among the new fields were several in the upper Permian limestones and sandstones on the west side of the platform, including Keystone (Winkler County, 1935), Keyes and Emperor (Winkler County, 1936), and Estes (Ward County, 1936). Some of the new fields produced oil from middle Permian limestones of the east side of the platform, such as Goldsmith, a major strike in Ector County, 1935, and also Cordova Union (Upton County, 1935), Foster (Ector County, 1935), Jordon (Ector County, 1937), and Dune (Crane County, 1938). An outstanding development was the extension of the producing area nearly 100 miles northward along the east side of the platform. Here many fields were found in the middle Permian limestones along minor folds that cross the edge of the platform. These included Means and Parker (Andrews County, 1934), Seminole (Gaines County, 1936), Bennett (Yoakum County, 1936), Duggan (Cochran County, 1936), and Wasson (Gaines County, 1937). Whether production will be found still farther north is problematic, because the limestones that contain the oil thin in that direction and become interbedded with anhydrite and red beds.

Another important development during the period was the discovery in 1935 of oil in Ordovician beds along the center of the Central Basin platform, in the Sand Hills oil field of Crane County. Further exploration was carried on south of this field, where the Ordovician formations rise gradually and are truncated by the overlying Permian. Late in the period discussed some oil was found in the Ordovician of northern Pecos County, as in the Magnolia Petroleum Co.'s McKee No. 1 well, and in the Masterson area, but deep drilling has not been extensive enough to prove its extent. It is a promising area for future exploration.

A small production was obtained from the Delaware sand in the Delaware Basin in the Mason field, northern Loving County, in 1937. Many wildcat wells have since been put down in the basin and exploration is continuing.

The other new discoveries in west Texas are east of the Central Basin platform. Some of them, as in Dawson, Garza, and Schleicher Counties, were far from any previously producing areas. None of the discoveries in this region, however, resulted in large production.

Most of the new fields in the region have been discovered as a result of geologic and geophysical work. Geologic work must be carried on mainly by subsurface study of wells that have already been drilled, because the surface formations, which range in age from Triassic to Tertiary, show none of the structure of the producing zones. Exploration by geologic methods is done by following out known structural or stratigraphic trends. Geophysical work is done either as pure exploration for structurally high areas in districts that have not been drilled or as a means of outlining structural features in areas in which some drilling has been done.

*East Texas.*—Prior to 1934 oil was produced in the east Texas district principally from the Woodbine sand, of Upper Cretaceous age, but beds of sandstone and limestone above the Woodbine yielded oil in comparatively small quantities. During the 5-year period 1934–38, however, producing zones in the Lower Cretaceous Glen Rose and Paluxy formations were discovered in such fields as Rodessa, Talco, and Cayuga. As these fields were developed they began and have continued to contribute significantly to the oil output of the district.

The oil pools are determined by structural or combined structural and stratigraphic traps. A score or more fields lie along the Mexia-Powell fault zone, where the oil is trapped in faulted anticlines. Other fields, such as Van, Cayuga, and Long Lake, are on anticlines along the west side of the east Texas basin. The east Texas field is a stratigraphic trap on the west flank of the large Sabine uplift.

In the 5-year period 1934–38, 16,018 oil wells were completed in east Texas. The drilling was distributed as shown in the following table:

TABLE 26.—*Annual oil production and oil wells reported completed in the East Texas district, 1934–38*

| Year | East Texas field | Remainder of East Texas district | Production (barrels) |
|---|---|---|---|
| 1934 | 3, 696 | 99 | 199, 008, 000 |
| 1935 | 3, 999 | 128 | 194, 981, 000 |
| 1936 | 2, 509 | 276 | 189, 594, 000 |
| 1937 | 2, 380 | 860 | 212, 003, 000 |
| 1938 | 1, 765 | 306 | 184, 367, 000 |

In this 5-year interval the east Texas field, the largest oil field of the world, maintained its dominance as a producer and virtually reached its full development in number of producing wells. At the end of 1938 the field had between 25,800 and 25,900 producing wells, had yielded more than 1¼ billion barrels of oil, and had a reserve estimated between 3½ and 4 billion barrels. The wells in this field average a little more than 3,600 feet in depth.

Prior to 1934 the dominance of the east Texas field in the east Texas district was even more decisive, as the only other fields were old, fully developed fields in the vicinity of Mexia and Powell and in the Nacogdoches area, in Nacogdoches County. These old fields had passed their peak of production, and in all the district outside of the east Texas field proper new oil wells were being completed at a rate of less than 100 a year. But with the discovery of productive zones in the Lower Cretaceous Paluxy and Glen Rose formations new oil wells were completed in increasing numbers as such new fields as Rodessa, Talco, Sulphur Bluff, Cayuga, and others were developed. In these fields most of the wells range in depth from 3,800 to 6,000 feet.

In the 5-year period 18 new fields and 5 new producing zones were discovered. Many of the new fields were found by deeper drilling to the Lower Cretaceous in structural features already known. Other structural features have been discovered by a combination of surface geology and reflection seismograph surveys.

The outstanding discovery and development in the district is the Rodessa field, which lies partly in the northwest corner of Louisiana and extends northeastward into Miller County, Ark., and southwestward into Cass and Marion Counties, Tex. The field is about 35 miles long and about 4½ miles in maximum width. It had been known as a gas field for several years prior to the discovery of oil, which resulted from deeper drilling in the Louisiana part of the field in 1935. Deep drilling was then etxended into Arkansas and Texas, and by the end of 1938 the 1,096 completed wells had produced a total of about 82,800,000 barrels of 43° gravity paraffin-base oil.

The Rodessa field is on the northwest flank of the Pine Island dome where the dip to the northwest is interrupted by a fault trending southwest and displacing the strata a few hundred feet down to the southeast. Oil has accumulated on the northwest side of the main fault, and the upthrown block has been broken. The rocks at the surface are of Eocene age (Sparta sand of Claiborne group), and oil is obtained at several horizons in the lower Glen Rose Limestone (Lower Cretaceous) at a depth of about 6,000 feet.

The reserves remaining in the Rodessa field were estimated in the latter part of 1937 to be a little more than a quarter of a billion barrels.

Active prospecting for pools in the Lower Cretaceous formations in the east Texas district may be expected to continue and to result in the discovery of new pools where these deeper formations have been folded or faulted into suitable traps or where adequate stratigraphic traps exist.

*Gulf coast district.*—In the Gulf coast district in the period 1934–38, 45 new fields and 53 extensions of known fields and new producing zones were discovered. In addition, old fields not previously drilled to their outer limits were extended. The peak year of discoveries was 1936, when 15 new fields were brought in and 12 important extensions were made.

The number of new oil wells completed increased each year in the 5-year period The production increased to a peak in 1937 and then decreased somewhat in 1938 The data for production and oil wells completed are given in the accompanying table.

TABLE 27.—*Oil wells completed and annual oil production in the Gulf coast district, Texas, 1934–38*

| Year | Oil wells completed | Production (barrels) |
|---|---|---|
| 1934 | 642 | 53,955,000 |
| 1935 | 720 | 57,025,000 |
| 1936 | 816 | 69,428,000 |
| 1937 | 1,174 | 83,713,000 |
| 1938 | 1,187 | 74,196,000 |

Of the new fields, 34 are on domes believed to overlie deep-seated salt plugs, 3 are on shallow salt domes, 4 on closed anticlines, 3 on anticlinal noses, and 1 on a structural terrace.

Thirty-six of the new fields were located by geophysical prospecting, five were the result of geologic studies supplemented by geophysical prospecting, two were discovered by geologic studies alone, and two were found by geophysical work in areas of surface indications, such as gas seeps and topographic irregularities. The torsion balance and reflection shooting with the seismograph have been the common geophysical methods used.

One of the most interesting of the new fields of the Texas Gulf coast district is the Cedar Point field, in Chambers County. This field is about a mile offshore in Galveston Bay on a sharply dipping faulted dome above a deep-seated salt dome. It was first located by torsion-balance work on floats and later checked by reflection seismograph. The first production was 642 barrels of 36.2° gravity oil in 24 hours through a ¼-inch choke with a tubing pressure of 990 pounds and with the casing sealed. This oil came from the Oligocene Frio sand at a depth of 5,956 to 6,030 feet. Oil was later obtained from a Miocene sand at 4,414 to 4,430 feet, which was revealed by electrical survey. This production from the Miocene was 263 barrels of 28.4° gravity oil on a ¼-inch choke with tubing pressure of 260 pounds and with the tube sealed. By the middle of 1938 the productive area was estimated to be about 500 acres and the ultimate recovery of the field to be about 36,000,000 barrels.

Most of the new discoveries are associated with deep-seated salt domes in the belt within 40 miles of the coast. The Cedar Point field in Galveston Bay probably will stimulate prospecting in other bay areas and offshore in the Gulf of Mexico. Much of the recent production from deep zones in the salt-dome belt near the coast has been high-gravity oil or distillate.

The discovery of the Kittrell field, in southern Houston County, in 1934 encouraged the hope that a new northern trend of salt-dome fields had been found, but considerable prospecting and wildcat drilling have failed to locate any additional fields along the inferred trend.

The opening of the San Felipe field, in southern Waller County, on the same trend as the Conroe field, stimulated activity along that trend but no new fields have been found.

The discovery of deep oil pools beneath old fields in 1937 and 1938 added materially to the known oil reserves of the district and encourages prospecting for deep zones in many other old fields. Two outstanding examples of development of this kind were afforded by the beginning of production from the deep Frio sand in the 20-year-old Orange and West Columbia fields. Oil may be obtained from still deeper beds in the belt of deep salt domes close to the coast, as zones deeper than the Frio have not been adequately tested.

*South Texas.*—South Texas may be divided geologically into three main belts—the Edwards Plateau at the northwest, a central belt of faulted Cretaceous formations, and a broad belt of Tertiary formations bordering the coast.

There has been very little activity in the Edwards Plateau, but some oil has been obtained at shallow depths from Ordovician and Pennsylvanian formations.

In the belt of faulted Cretaceous formations about 50 oil fields have been developed, most of them in the last few years. Most of the production is obtained from fault-line traps. The rock formations dip southeast and are broken by faults that are roughly parallel with the coast. Most of the faults are dropped on the southeast side, and the oil is trapped against the faults. The Luling and Darst Creek fields are examples. The oil is obtained from several zones in the Lower and Upper Cretaceous formations, usually at a depth less than 3,000 feet. However, in 1938 the Chriesman field, in Burleson County, produced oil from the up-dip edge of a fault block of Edwards limestone (Lower Cretaceous) at a depth of 6,167–6,173 feet, suggesting that oil may be obtained from the Cretaceous formations southeast of the present producing trend.

In the broad belt of Tertiary formations oil is produced from the Eocene, Oligocene, and Miocene formations. This belt can be divided into two parts on the basis of the usual type of oil occurrence.

In the western part of the belt the oil is usually found in stratigraphic traps associated with minor folds or faults, as in the Casa Blanca, Cedro Hill, Alice, Ezzell, Escobas, Comitas, and Cuevitas fields. The producing sands are commonly elongated in a northeasterly direction and wedge out abruptly on the west or up-dip side. In some of the fields the accumulation is due to structural closure, locally on closed folds, as in the Cole field, and locally against faults, as in the Fitzsimmons field. A few of the fields are salt domes—for example, Palangana and Piedras Pintas.

More than 100 fields have been developed in this western part of the Tertiary belt, most of them discovered in the last few years. It is estimated that the ultimate yield per acre for most of the fields will range from 5,000 to 12,000 barrels. The gravity of the oil is usually a little over 40°.

In the coastal part of the belt a few dozen fields have obtained production from anticlinal folds, some of which are faulted. The Saxet, Luby, Greta, and Refugio fields are examples. In these fields oil has not yet been found below the Oligocene, but production may be extended to considerably greater depths when the Eocene and Cretaceous formations are more fully tested.

During the period, 1934-38, the oil production of the south Texas district mounted rapidly and at a nearly uniform rate. New oil wells completed each year also increased steadily until 1938, when the number fell off somewhat. The increase in production and the number of new oil wells completed per year are shown in the accompanying table.

Table 28.—*Oil wells completed and annual oil production in the South Texas district, 1934–38*

| Year | Oil wells completed | Production (barrels) |
|---|---|---|
| 1934 | 709 | 28,390,000 |
| 1935 | 1,158 | 34,678,000 |
| 1936 | 2,471 | 52,801,000 |
| 1937 | 2,533 | 75,340,000 |
| 1938 | 1,751 | 82,569,500 |

In the 5-year interval 143 new oil pools and more than 160 new producing zones in already established fields or in new fields have been discovered in south Texas. In general, the new pools have been found at progressively greater depths. Most of the new fields in the coastal belt are now producing from depths of 5,000 feet or more, and the average depth from which all the new fields in the south Texas district are producing is a little more than 4,000 feet. During 1938 the first well in Texas to produce at a depth greater than 9,000 feet was drilled in the Weslaco field, Hidalgo County. The total depth of this well was 9,185 feet, and although it produced from a zone between 8,995 and 9,005 feet, it was later plugged back to 8,634–8,642 feet, where it produced distillate and gas. The deepest well in Texas, 13,728 feet, is in the Agua Dulce field, in Nueces County, but it produces from zones between 8,000 and 9,000 feet. Most of the new fields were discovered by geophysical prospecting and exploratory drilling.

It is probable that geophysical prospecting will continue to be active in searching out structural features along the coast and in bay and Gulf waters. Such features will have to be tested by deep drilling, but production is to be expected from suitable traps. Subsurface geology should play a significant part in working out these deeply buried structural features, as the faults appear to increase in displacement downward. Subsurface geology will probably also be useful in delineating sand trends, stratigraphic traps, and structural traps in the productive belts back from the coast. It is to be expected that south Texas will continue to be actively prospected and that many new oil pools will be discovered there.

## Gulf Coast Region

Developments in the Gulf coast of Texas and Louisiana and exploration for oil in the Gulf coast of Mississippi are described in the summaries of these States under the heading "Midcontinent region."

## ROCKY MOUNTAIN REGION

(Colorado, Montana, northwestern New Mexico, Utah, and Wyoming)

### COLORADO

Colorado has been a steady producer of oil since the discovery of the Florence field, Fremont County, in 1862. Its total output of oil to the end of 1938 was about 37,000,000 barrels. The State's proved reserves January 1, 1939, are estimated to be about 17,713,000 barrels. During the period 1934–38 about 125 wells were drilled in Colorado, and the State produced 7,366,000 barrels of oil, more than half of which came from the Iles field, in Moffat County.

The most interesting of the new discoveries in the period following 1933 was in Moffat County, where oil was found in the Wasatch formation (Eocene). Some oil had been encountered in the Wasatch in the Hiawatha gas field in 1934, and commercial production was obtained from two zones in that formation in the Powder Wash field in 1936. In 1937 the Wasatch was tested in the Dry Mountain, Shell Creek, and Vermilion Creek anticlines, but the wells drilled were dry. The results suggest that, although the Wasatch may contain oil locally, there is probably no considerable reserve of oil in the formation.

The Powder Wash anticline is one of a series of small domes on the south side of the Washakie Basin. The oldest rocks at the crest are Wasatch; on the flanks are Green River (Eocene) and Browns Park (late Tertiary) formations. The closure is about 100 feet, and the closed area about 5,000 acres. The two oil zones are at depths of 3,085 and 5,014 feet. The upper zone tested 1,000 barrels daily; the lower, near the base of the formation, tested 1,100 barrels daily. The oil is of 39.9° American Petroleum Institute gravity. The field has not yet been adequate developed.

The Price field, in Archuleta County, was discovered in 1934. This field is on a narrow, sharp fold, on the crest of which the Mancos shale (Upper Cretaceous) is exposed. The anticline is almost surrounded by extrusive igneous rocks. Oil is produced from the Dakota (?) sandstone (basal Upper Cretaceous) at 970 to 1,400 feet. The field was reported to have yielded a small amount of light oil in 1936. In 1937 it was partly defined to the northwest, north, and southwest by the drilling of marginal dry wells. The Price field was the State's second largest producer in 1937 and 1938.

In 1937 oil was discovered in the Wilson Creek dome, in Rio Blanco County, in the Morrison formation (Jurassic) at a depth of 6,664–6,704 feet. The fold is a large dome along the Danforth Hills line of folding. It has about 1,000 feet of closure, and the closed area is about 15,000 acres. During the last 6 months of 1938 the discovery well produced 60,150 barrels of oil, with a gravity of 46° American Petroleum Institute. With only the one well on the dome, however, it is not possible to estimate the areal extent of the pool.

In eastern Colorado extensive geophysical prospecting has been done, and 10 deep wells have now tested the deeply buried Paleozoic formations. All of these have been dry wells, but although they offer little encouragement to further deep drilling the huge area cannot yet be regarded as fully tested.

### MONTANA

The State of Montana contains many structural features apparently favorable for the accumulation of oil and gas, and most of these have been tested by the drill, but only a few important fields have been found. Most of the commercially important fields are confined to three districts—the Sweetgrass arch district, in Toole, Glacier, and Pondera Counties, including the Cut Bank, Kevin-Sunburst, and Pondera fields; the southern district, including the Lake Basin and Dry Creek fields; and the central district, containing the Cat Creek field. Oil accumulations are found in anticlines, domes, lenticular sands, and, locally, in lenses of greater porosity. Commercial amounts of oil occur in both Mesozoic and Paleozoic strata. Future prospecting will probably be done in large part in older formations in areas where the structure is known to be favorable but inadequately explored.

TABLE 29.—*Annual oil production in Montana, 1934–38, by fields*

[Thousands of barrels]

| Year | Border | Cat Creek | Cut Bank | Dry Creek | Elk Basin | Kevin-Sunburst | Lake Basin | Pondera | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1934 | 70 | 236 | 1,204 | (1) | 16 | 1,628 | 16 | 363 | 70 | 3,603 |
| 1935 | 40 | 311 | 2,321 | (1) | 11 | 1,371 | (1) | 441 | 108 | 4,603 |
| 1396 | 43 | 258 | 3,332 | 214 | 12 | 1,543 | (1) | 433 | 33 | 5,868 |
| 1937 | 41 | 227 | 3,332 | 102 | 12 | 1,634 | (1) | 418 | 39 | 5,805 |
| 1938 [2] | 22 | 209 | 2,770 | 338 | | 1,271 | | 212 | | 4,907 |

(1) Included under "Other."
[2] Figures for 1938 are preliminary and incomplete.

The most notable oil developments in Montana during the period 1934–38 were substantial extensions to the Cut Bank and Kevin-Sunburst fields, in Glacier and Toole Counties, respectively, and the increased recovery of oil in the latter field through acid treatment of wells. Owing to the steady expansion of these two fields, which produced more than three-fourths of the output of the State during the 5-year period, Montana's production was increased materially over that of 1933, and discovery of new reserves kept pace with production. The estimate of Montana's oil reserves at the end of 1933 was 57,000,000 barrels, and the estimate for January 1, 1939, was 104,471,000 barrels. A decline in production and drilling activity began in the latter part of 1937 and continued through 1938. Only about half as many wells were completed in 1938 as in 1937. A summary of production and well data is given in the accompanying table.

TABLE 30.—*Wells drilled in Montana, 1934–38*

| Year | Oil | Gas | Dry | Total |
|---|---|---|---|---|
| 1934 | 127 | 21 | 36 | 184 |
| 1935 | 131 | 17 | 38 | 186 |
| 1936 | 166 | 34 | 47 | 247 |
| 1937 | 135 | 26 | 56 | 217 |
| 1938 | 69 | 21 | 27 | 117 |
| Total | 628 | 119 | 204 | 951 |

The Cut Bank field is at present Montana's most active and productive field. Gas was discovered here in 1926, but oil was not obtained until 1931, and prior to 1934 the field produced only about 300,000 barrels of oil. In the period 1934–38 Cut Bank produced nearly 13,000,000 barrels of oil—nearly 50 percent of the total production of the State for that period. The Cut Bank field includes a gas-producing area about 85 square miles in present extent, which is flanked on the west by an oil area roughly 4 miles wide and 25 miles long, and its boundaries have not been fully defined. Oil is obtained chiefly from the Cut Bank sand—the basal sandstone zone of the Kootenai formation (Lower Cretaceous)—but is also found locally in beds of sandstone higher in the Kootenai. Its accumulation is a consequence of up-dip migration into stratigraphic traps, of which there are several types. In the northern part of the oil area structural deformation has tended in general to increase the effect of the stratigraphic traps. To the end of 1938 a total of 562 wells had been drilled in the Cut Bank field, at an average drilling depth of 2,975 feet in the oil-producing area. The present average daily production per well for the area is 26 barrels. Oil from the Cutbank sand is of intermediate base and ranges in gravity from 36° to 39.4° (American Petroleum Institute).

The Kevin-Sunburst field, in Toole County, produced more oil than any other field in Montana up to the end of 1938—nearly 35,000,000 barrels. It was discovered in 1922, reached its peak in 1926, then declined gradually to a low point of 1,237,000 barrels in 1933. Acid treatment of the wells, begun about that time, has been found very effective in stimulating production not only in the new wells but in old wells that apparently were approaching exhaustion. The West Kevin field, where most of the development of the period 1934–38 took place, is a northwestward prolongation of the main Kevin-Sunburst field and is developed along two rather broad anticlinal noses that plunge westward and northwestward, respectively, across T. 35 N., Rs. 3 and 4 W. It contains 229 wells, of which 117 produce oil. In the West Kevin field oil is found in the eroded and weathered top of the Madison limestone, in the basal sandstone of the Ellis formation, and in the Sunburst sand in the upper part of the Kootenai formation. The entire Kevin-Sunburst district had 1,162 producing wells at the end of 1938. With the exception of the Cut Bank and Kevin-Sunburst fields, the other active fields in Montana continued production without material change during 1934–38.

The only significant discovery of oil in Montana in the last 5 years outside of extensions to areas already producing was in the extreme eastern part of the State, in Fallon County, on the Little Beaver Dome, a local "high" on the crest of the Cedar Creek (Baker-Glendive) anticline. The anticline is more than 100 miles long and for many years has yielded gas from the Judith River formation, of Upper Cretaceous age. In 1936 a deep test hole in T. 4 N., R. 62 E., found black oil in the Mississippian and Devonian(?) at 6,747 and 8,186 feet, respectively. In 1937 a second well in the same township obtained oil in the Mississippian at 6,766 feet. Most of a reported production of about 15,000 barrels of oil from these two wells has gone into storage. This discovery of oil remote from any other area of production will encourage exploration of Mississippian and Devonian strata in the neighboring States of North and South Dakota.

In 1936 oil was discovered in the Cloverly sandstone at a depth of about 1,000 feet in a well in sec. 26, T. 3 S., R. 24 E., on the Mosser anticline, Yellowstone County, and subsequently several other wells drilled in the same section obtained small amounts of oil. However, the wells were quickly abandoned, owing to water encroachment. In the Sweetgrass Hills district a little oil was obtained in 1935 on the Flat Coulee dome, Liberty County, 2 miles south of the Canadian border, at 2,879 feet, in the basal Kootenai, but there has been no further development. The possible productive area is about 1 square mile.

The possibilities for oil production from the untested deeper zones in the Big Lake anticline, in Stillwater County, and the Broadview dome, in Yellowstone County, were tested by drilling in 1938. One well on each of these features was abandoned after apparently drilling about 800 feet below the top of the Madison limestone.

### NEW MEXICO

Developments in northwestern New Mexico are described in the summary of that State under the heading "Mid-Continent region."

### UTAH

In the period 1934–38 no new oil fields were discovered in Utah, and the developments did not improve the prospects in the Virgin and San Juan fields, the only two fields. There is only 610 acres of proved oil land in Utah, 450 acres in the Virgin field and 160 acres in the San Juan field. In the 5-year period the State's production of oil averaged only about 3,000 barrels annually, and practically all of it came from the Virgin field.

In 1935 the Sundance formation was tested at a depth of 6,790 feet in the Clay Basin gas field, Daggett County, but failed to yield oil, although encouraging results had been obtained from similar tests in nearby parts of Wyoming and Colorado.

In 1937 a well completed on the San Rafael Swell encountered schist of the crystalline basement at 4,855 feet. This was the fifth well to drill to the crystalline basement in southeastern Utah, the others being two in the San Juan field, one on Elk Ridge, and one near Cisco. Southeastern Utah has offered little encouragement to further wildcat drilling. The exploratory drilling has tested virtually all the known structural traps, so it seems probable that if any oil is found in that part of the State it will be found in less easily discoverable stratigraphic traps.

The discovery of oil in the Wasatch formation (Eocene) in the Powder Wash and Hiawatha anticlines, Moffat County, Colo., suggested that oil might be found in the Wasatch in Daggett and Uinta Counties, Utah, but the prospects were seriously diminished by the subsequent failure of wells drilled into the Wasatch on the Dry Mountain, Shell Creek, and Vermilion Creek anticlines, all of which are in adjacent Moffat County, Colo.

### WYOMING

Oil production in Wyoming rose from 11,227,000 barrels in 1933 to 19,004,000 barrels in 1938—an increase of 70 percent for the 5-year period. The gain occurred principally in 1937, when the production increased 4,584,000 barrels over 1936, owing in large part to the development of deeper productive zones in the Lance Creek field and to the discovery of the new Medicine Bow field.

Wyoming has 61 oil or oil and gas fields, and 20 gas fields. They are widely distributed over the State, but most of them have been found near the margins of the broad intermontane basins, where the oil-bearing rocks, ranging from Mississippian to Eocene in age, have been folded into anticlines and domes. All but four of the fields are on anticlines or faulted anticlines, and over 98 percent of the oil produced in 1938 came from the anticlinal folds.

The Salt Creek field has been for many years not only the largest field in Wyoming, but the largest in the entire Rocky Mountain region. To the end of 1938 it had produced 62 percent of the State's oil, and on the basis of total cumulative production it was in thirteenth place among the producing fields in the United States on January 1, 1938. Throughout the 5-year period, 1934–38. however, production from the Salt Creek field has been declining gradually (from 6,520,000 barrels in 1934 to 4,496,620 barrels in 1938), and in 1938 it was exceeded in production by the Lance Creek field.

The Lance Creek field, in the eastern part of the State, is on an asymmetric anticlinal fold, about 30 miles west of the east boundary of the State, in Niobrara County. Here oil was discovered in the Dakota sandstone (Cretaceous) in 1918. In 1932 oil was found in the upper part of the Sundance formation (Jurassic), and in 1934 larger production was obtained from the lower part of the Sundance. In 1937 a still deeper zone, the Leo sand, in the Minnelusa formation (Pennsylvanian), was found to be a prolific producer. In 1938 Lance Creek was Wyoming's largest field, yielding 4,573,368 barrels, or 24 percent of the State's production for that year. The production in 1938 from the deeper zones of the Lance Creek field accounts for 58 percent of the increased production of 1938 over 1933 (7,777,000 barrels).

The 9 new oil fields that were discovered in 1934–38 produced nearly 10 percent of the 1938 total, and this combined with the production from deeper beds in the Lance Creek field made up one-third of the 1938 total. The Medicine Bow field, in Carbon County, is by far the most productive of the new fields, with an output in 1938 of 1,132,723 barrels. In 1937 oil was discovered in the Tensleep formation (Pennsylvanian) on the Wertz Dome, which is also in Carbon County. By the end of 1938 this field had produced 388,808 barrels of oil. Prior to 1937 the Wertz Dome had yielded gas from Mesozoic rocks. Oil was discovered on the Quealy Dome, in Albany County, in 1934, and in 1938 it produced 270,967 barrels from the Muddy-Dakota sands, of Upper Cretaceous age. The Cole Creek field, in Natrona County, was discovered in May 1938 and produced 23,161 barrels from the Lakota sand (Lower Cretaceous) at a depth of more than 8,000 feet. The combined total of the other five new fields was less than 20,000 barrels in 1938.

The Medicine Bow anticline is one of the most conspicuous anticlines in the Laramie Basin. It is a pronounced asymmetric fold about 3 miles wide and 7 miles long and has a surface closure of about 2,900 feet. Prior to 1934 seven wells favorably located as to structural position had been drilled on the anticline, but none of them penetrated the underlying formations deep enough to reach the Sundance (Jurassic) oil-bearing strata. In 1935 light oil of 63° gravity (American Petroleum Institute) was found in the second Sundance sand at a depth of 5,300 feet.

The following table shows the annual oil production in Wyoming for the 5-year period, the number of wells drilled each year, and the results obtained.

TABLE 31.—*Annual oil production and number of wells drilled in Wyoming, 1934–38*

| Year | Oil produced (barrels) | Wells drilled | | | |
|---|---|---|---|---|---|
| | | Total | Oil | Gas | Dry |
| 1934 | 12,556,000 | 67 | 44 | 9 | 14 |
| 1935 | 13,755,000 | 92 | 58 | 6 | 28 |
| 1936 | 14,582,000 | 131 | 88 | 8 | 35 |
| 1937 | 19,166,000 | 127 | 72 | 12 | 43 |
| 1938 | 19,004,000 | 157 | 95 | 19 | 43 |

During these 5 years more attention was paid to gas drive or recirculation of gas, to the systematic spacing of wells, and to the coring of producing zones. The use of electrical logging for well correlation began in 1936. There has been active geophysical prospecting, particularly in the intermontane basin areas, and in 1936 more than a dozen seismograph crews were in the field. The same year about 80 miles of pipe line was laid, and in 1938 a pipe line was laid from Lance Creek to Denver, a distance of 232 miles.

In the Lance Creek field a unit plan of development and operation of the basal Sundance sand went into effect in January 1938. Under this plan a gas-injection plant was constructed and placed in operation which takes the daily surplus of 6,000,000 to 8,000,000 cubic feet of gas and returns it to the basal Sundance sand through five gas-injection wells near the crest of the fold.

The search for new sources of petroleum in Wyoming will probably continue the present trend of exploration for oil from deeper zones in the existing fields, and on those structural features that were found to be nonproductive by shallow drilling. Geophysical prospecting and deeper drilling have combined to widen the belt being tested along the margins of the intermontane basins.

## California

The oil produced in California comes mainly from three areas—the Los Angeles Basin, which has yielded 47 percent of the State's oil to date; the margins and central portion of the southern San Joaquin Valley, which has yielded 43 percent; and the coastal region, which has yielded 10 percent.

The Los Angeles Basin, 45 miles long and 25 miles wide, is a plains region bounded on the west and south by the Pacific Ocean and on the north and east by hills and mountains of the Coast Ranges. The city of Los Angeles is on the northern border of the basin. The oil in the basin is found in anticlines, most of which are faulted, in sedimentary beds of lower Pliocene and upper Miocene age.

In the San Joaquin Valley the oil fields are scattered from the vicinity of Coalinga southeastward to the south end of the valley. The oil is found in anticlines, in faulted areas, beneath unconformities, and in inclined strata whose upper parts are sealed by tar or by changes in permeability of the strata. The oil comes mainly from formations of Eocene, Miocene, and Pliocene age, but a little is obtained from beds of Cretaceous age.

The coastal fields lie principally in two groups—the Santa Maria fields, which lie in the Santa Maria Basin, in western Santa Barbara County; and the Santa Barbara and Ventura fields, which extend eastward along the coast of Santa Barbara and Ventura Counties from Capitan to Ventura and thence inland along the borders of the Santa Clara Valley to Newhall, a total distance of about 90 miles. The oil in these fields is encountered mainly in anticlines, but some is found below unconformities. It comes principally from Pliocene and Miocene strata, but a little is found in beds of Eocene age.

*Production.*—California during the 5-year period between January 1, 1934, and January 1, 1939, produced 1,085,140,000 barrels of oil, an average of about 200,000,000 barrels a year. The production has risen each year, increasing from 172,010,000 barrels in 1933 to 249,749,000 barrels in 1938. The greatest increase was in 1934, when 33,000,000 more barrels was produced than in 1933. Throughout the 5-year period production has been curtailed by mutual consent of the operating companies, and in each year the potential daily production was about double the amount actually produced. In 1938 the average daily production was 685,000 barrels, and at the end of the year the potential was estimated to be more than 1,400,000 barrels a day.

*Reserves.*—The rate of discovery of oil in new fields in California has varied from year to year. During the 5-year period 1934–38, as indicated in table 32, 816,000,000 barrels of new oil was discovered. This quantity failed by 270,000,000 barrels to equal the amount of oil withdrawn from the ground. The proved reserves, therefore, decreased from 3,417,000 barrels in 1934 to 3,147,000 barrels in 1938. It is difficult to obtain accurate data on the amount of oil discovered each year, because the estimates of the amount of oil in the individual fields change from year to year as additional information is obtained from new wells that are drilled, but only the total reserves for the State at the end of each year are published. Moreover, different estimates are made by different authorities. For example, the American Petroleum Institute reports a proved reserve of 3,188,000,000 barrels for the year 1939, as compared with 3,147,000,000 barrels as given by Hoots and shown in table 32.

TABLE 32.—*Reserves, annual production, and discoveries of oil in California, 1934–38, in thousands of barrels*

| Year | Proved reserves at beginning of year [1] | Production during year [2] | Percentage increase in production over previous year | New reserves discovered during year [3] | Excess or deficiency of withdrawals over new oil discovered during year | |
|---|---|---|---|---|---|---|
| | | | | | Excess | Deficiency |
| 1934 | 3, 417, 000 | 174, 305 | 1. 3 | 61, 000 | 113, 000 | |
| 1935 | 3. 304, 000 | 207, 832 | 19. 1 | 11, 000 | 197, 000 | |
| 1936 | 3, 107, 000 | 214, 773 | 3. 3 | 168, 000 | 47, 000 | |
| 1937 | 3, 060, 000 | 238, 521 | 11. 1 | 323, 000 | | 84, 000 |
| 1938 | 3, 144, 000 | 249, 749 | 4. 7 | 253, 000 | | 3, 000 |
| 1939 | 3, 147, 000 | | | | | |
| Total | | 1, 085, 180 | [4] 45. 0 | 816, 000 | 270, 000 | |

[1] Hoots, H. W., American Association of Petroleum Geologists Bull. vol. 23, p. 933, 1939.

[2] Bureau of Mines.

[3] Excess of reserves at end of year over reserves at beginning of year, less withdrawals during year.

[4] For 5-year period.

The estimates of new reserves presented in table 32 were calculated from the figures for total reserves and annual production given in that table. Inasmuch as the estimates of reserves in previously discovered fields may have been revised during the year, the figures for new oil discovered may not be exact, but they are probably of the right order of magnitude, particularly the totals for the 5-year period.

On this basis, the new discoveries of oil were lowest in 1935 (11,000,000 barrels) and the greatest in 1937 (323,000,000 barrels). During 1934, 1935, and 1936 the production exceeded the discovery of new oil by 357,000,000 barrels, but in 1937, 84,000,000 barrels more oil was found than was removed from the ground. In 1938 the withdrawals about equaled the discoveries. During the 5-year period, though more than a billion barrels of oil was removed from the ground, the amount of reserves declined only 270,000,000 barrels.

*Number of wells drilled.*—The total number of wells completed in California in the 5-year period 1934–38 was 5,587. Of these wells, 1,492, or 26.7 percent, were dry and 4,095, or 73.3 percent, produced oil. About one-half the dry wells, or 710, were drilled remote from proved territory and are classed as wildcats. Of these, 24, or 3.4 percent, discovered oil and resulted in the development of new fields. The percentage of successful wildcat wells range from 1.7 in 1934, when 1 new field was discovered, to 5 percent in 1936, when 6 new fields were found. Nine fields were found in 1937, but as the number of wildcat wells was greater, the effectiveness of wildcat wells for that year was slightly less than in 1936.

TABLE 33.—*Number of oil-producing and dry wells drilled in California, 1934–38*

| Year | Total wells | Producing oil wells | Dry holes | Percentage of dry holes | Wildcat wells | Wildcat wells that produce oil | Percentage of wildcat wells that produce oil |
|---|---|---|---|---|---|---|---|
| 1934 | 696 | 449 | 247 | 35. 5 | 60 | 1 | 1. 7 |
| 1935 | 1, 057 | 710 | 347 | 32. 9 | 89 | 2 | 2. 3 |
| 1936 | 1, 106 | 786 | 320 | 28. 9 | 120 | 6 | 5. 0 |
| 1937 | 1, 469 | 1, 156 | 313 | 21. 3 | 209 | 9 | 4. 3 |
| 1938 | 1, 259 | 994 | 265 | 21. 0 | 232 | 6 | 2. 6 |
| Total | 5, 587 | 4, 095 | 1, 492 | 26. 7 | 710 | 24 | 3. 4 |

*New discoveries.*—During the 5-year period 1934–38, 24 new fields were discovered in California. In addition, 8 old fields were extended and deeper zones were encountered in at least 8 proved fields (table 34). Of the new fields, 1, the Edison field, was discovered in 1934; 2, the El Segundo and Reserve-Tejon Ranch fields, in 1935; 6, the Greeley, Tejon Ranch (Grapevine), Padre Canyon, Santa Maria Valley, Ten Section, and Wilmington fields, in 1936; 9, the Arvin, Canal, Newhall-Potrero, North Round Mountain, Oxnard, Pyramid Hills, Rio Bravo, Tampico, and Yorba fields, in 1937; and 6, the Las Flores, Aliso Canyon, Coles

Levee, East Coalinga, Richfield-Western, and Wasco fields, in 1938. Four of the eight new extensions—(1) the areas producing from the Eocene at the north end of the Kettleman Hills field, (2) the Hilldon area at the northeast end of the Long Beach field, (3) the Canfield area, in the Ten Section field, and (4) the Miocene area at the west end of Montebello—perhaps might be considered separate fields and thus would bring the total of new fields to 28. The 8 areas in which deeper zones are indicated in table 34 represent the more productive areas. Deeper zones were also developed in several other fields.

TABLE 34.—*New discoveries of oil in California, 1934–38*

| Year | In wild cat areas | In extensions of old fields | In deeper zones in old fields | Methods of discovery in wildcat areas | | |
|---|---|---|---|---|---|---|
| | | | | Geology | Geophysics | Combination of geology and geophysics |
| 1934 | 1 | 1 | 2 | 1 | | |
| 1935 | 2 | 1 | 1 | 1 | | 1 |
| 1936 | 6 | 1 | 1 | 3 | 2 | 1 |
| 1937 | 9 | 2 | 2 | 4 | 3 | 2 |
| 1938 | 6 | 3 | 2 | 3 | 3 | |
| Total | 24 | 8 | 8 | 12 | 8 | 4 |

Geophysics aided in the discovery of some of these new fields, especially in the San Joaquin Valley. Seven out of the 24 fields—the Canal, Coles Levee, Greeley, Richfield-Western, Rio Bravo, Ten Section, and Wasco—were discovered by means of the reflection seismograph. These fields are all on the floor of the San Joaquin Valley and represent an addition of at least 500,000,000 barrels of oil to known reserves. The wells in these areas are from 8,000 to 13,000 feet deep and produce mainly from two zones, one near the top of the Miocene and one near the bottom.

The Oxnard field, in the Ventura Basin about 50 miles west of Los Angeles, was discovered by means of magnetometer and resistivity surveys. The oil is found in the Pliocene. Four fields, the El Segundo and Wilmington fields, in the Los Angeles Basin; the Newhall-Potrero field, 30 miles northwest of Los Angeles; and the Arvin field, 15 miles southeast of Bakersfield, on the east side of the San Joaquin Valley, were discovered by means of a combination of geologic and seismograph work. The remaining 12 fields were found mainly with the aid of surface and subsurface geologic investigations.

*Outstanding areas.*—Four areas stand out during this 5-year period. These are the Wilmington field, in the Los Angeles Basin; the Santa Maria Valley field, 130 miles northwest of Los Angeles; the several fields on the floor of the San Joaquin Valley near Bakersfield; and the area of Eocene production near Coalinga, a few miles north of the Kettleman Hills. The fields in these four areas accounted for most of the reserves discovered in California during the 5 years.

Wilmington field: The Wilmington field was discovered in the Los Angeles Basin in the vicinity of Los Angeles Harbor in December 1936, as a result of geologic interpretation of subsurface data followed by seismograph surveys. The field is on a faulted anticline, on which the limits of production are not yet completely known. Thus far 3,200 acres has been found productive. The oil is found in five zones in the basal part of the Pliocene and the upper part of the Miocene through an interval of about 3,000 feet. On the crest of the anticline the oil is first encountered at a depth of about 2,500 feet. The gravity of the oil increases from 14° (American Petroleum Institute) in the highest zone to about 30° (American Petroleum Institute) in the lowest zone. The third and fourth zones, in the uppermost part of the Miocene, are the most productive. The third zone is 600 feet thick and the fourth zone 500 feet. Wells producing 4,000 barrels a day have been brought in from each of these two zones. Relatively little gas is produced with the oil. In places the wells are closely spaced, and the field has been drilled up rather rapidly, 588 wells having been drilled to January 1, 1939. The total production to that date was 48,000,000 barrels, of which 34,000,000 barrels was produced in 1938. The reserves of the field have been estimated at 400,000,000 barrels.

Santa Maria Valley field: In April 1936 oil was obtained from the Miocene beds in the Santa Maria area, which is near the ocean, 130 miles northwest of Los Angeles. Hitherto this area has yielded oil from the Pliocene. The Miocene oil occurs in inclined strata unconformably overlain by Pliocene beds. It was discovered as a result of geologic interpretation of surface and subsurface mapping, and it is found in an elongate area 7 miles long and 1 to 2 miles wide. The main production is derived from a zone of fractured cherty shale in the upper part of the Miocene. Some oil is also encountered in a lower sand, which has not yet been developed extensively but is believed to be less productive than the upper. Owing to local unconformities in the Miocene it lies at variable depths but not more than 1,000 feet beneath the upper zone. The oil in the field is found at depths ranging between 2,000 and 5,300 feet beneath the surface. The field is remarkable in that oil is present in a single zone throughout a depth interval of more than 3,000 feet. The limits of production have not yet been ascertained, but at least 6,000 acres is productive. The daily production of different wells ranges from 100 to 7,000 barrels, apparently owing to differences in degree of fracturing of the shale. The gravity of the oil ranges mainly between 15° and 18° (American Petroleum Institute). Relatively little gas is encountered, the gas-oil ratio being about 200. The field produced 6,487,000 barrels to January 1, 1939. The reserves are in excess of 150,000,000 barrels.

Wasco field: The Wasco field, 15 miles northwest of Bakersfield in the middle of San Joaquin Valley, was discovered in April 1938 as a result of reflection seismograph surveys. The discovery well, the deepest well in the world, was drilled to a depth of 15,004 feet but was put on production from a lower Miocene zone between 13,100 and 13,177 feet. It yielded at the rate of 3,000 barrels of oil. The gravity of the oil is 35° (American Petroleum Institute). The field lies on an anticline, but the total area of production is not yet known, as only two wells had been completed prior to January 1939. The Stevens sand zone, in the upper part of the Miocene, which has yielded oil in several places in the San Joaquin Valley, was barren, as was also the Eocene sand at the bottom of the well. The field produced 125,000 barrels of oil to January 1, 1939. The reserves are estimated to be of the order of 40,000,000 barrels.

East Coalinga field: The outstanding development in California during 1938 was the discovery in July of oil in the upper part of the Eocene a few miles east of Coalinga, on the west side of the San Joaquin Valley, 8 to 10 miles northwest of the great Kettleman Hills oil field. The field was discovered by means of geologic interpretation of subsurface and surface geology. The oil occurs in a very porous sand, 300 to 600 feet thick, on the flanks of the Coalinga anticline, which is the northward extension of the Kettleman Hills anticline. The sand changes to shale up the flanks of the anticline, and the impervious shale forms a trap for the oil. The limits of production are not yet known, but at least 1,000 acres is productive, and probably very much more. because in April 1939 a well was brought in from the Eocene about 5 miles northeast of the field, and presumably the oil is continuous between. The oil is produced in this Eocene zone from depths ranging mainly between 6,000 and 8,000 feet. High yields have been obtained from the wells thus far drilled, and the recovery is estimated to be 75,000 barrels per acre. The discovery well had an initial yield of 7,920 barrels of oil on a 1-hour gage and an estimated 7,000,000 cubic feet of gas. The gravity of the oil is 33° (American Petroleum Institute). Thirteen wells had been drilled to February 1939. All these wells have been greatly curtailed since completion, and to the end of 1938 the field produced only 250,000 barrels of oil. The reserves January 1, 1939, were estimated to be 75,000,000 barrels, but they will probably exceed that considerably in the light of the more recent well completions.

*Areas of active interest and future possibilities for discoveries of oil.*—The San Joaquin Valley at present is the area of most active interest in California. During the last 5 years several large fields have been found at considerable depth on the floor of the valley, and it is probable that additional fields will still be discovered in this area. The fields in this area have all been found with the aid of geophysical prospecting, and further search by this method can be expected for some time to come.

The discovery of oil in the Eocene east of Coalinga has opened the way to very active prospecting by geologic methods along the west side of the San Joaquin Valley. In the East Coalinga field a sand in the upper part of the Eocene grades into an impervious shale on the flanks of the Coalinga anticline, and oil is trapped against this shale. Sand is found beneath other parts of the floor of the San Joaquin Valley, in what is believed to be the same stratigraphic zone. The sea in which this sand was deposited apparently deepened westward, so that the sand changed laterally to shale. South of Coalinga the sand may also grade into shale on the west side of the San Joaquin Valley, thus forming, in favorable places, a trap for the accumulation of oil. One of the difficulties in locating such places is the uncertainty of correlating this sand westward, and at present many of the oil companies and the Geological Survey of the United States Department of the Interior are making detailed stratigraphic studies of the Eocene in order to locate possible places where this sand grades into shale. As this sand is believed to be present for 100 miles southeast of Coalinga, there is a very large area of it in which oil may possibly be found.

The Miocene in the San Joaquin Valley contains several unconformities, particularly on the sides of the valley. As oil may possibly be trapped in sand bodies that are truncated by overlying impervious shales, considerable search is now going on for such unconformities. The south and west sides of the valley are particularly favorable areas. This search is carried on mainly by subsurface and surface geologic studies.

The Santa Maria area, 50 miles west of the San Joaquin Valley, also offers additional possibilities for oil, because several unconformities are known to exist in the Miocene in this region and considerable oil may yet be found to be trapped against some of the unconformable beds. The high sulfur and low gasoline content of the oil in this area, however, have temporarily discouraged active prospecting.

Unconformities also exist in the Pliocene beds in the Los Angeles Basin, and some oil may yet be found in this area. The oil companies continue to give attention to the Los Angeles Basin, but at present it is not being actively prospected. Additional deep zones may be found in a few areas, but as most of the fields in the basin have had deep tests, it is likely that not much more oil will be found in old fields at greater depths though the fields may be extended. The Miocene in the Ventura Avenue field, 70 miles west of the Los Angeles Basin, however, has been little tested and offers considerable promise of yielding oil at greater depth.

The coastal area west of Santa Barbara is underlain by Miocene beds and may yield oil, but prospecting is difficult owing to the complicated structure and the overburden of soil and alluvium.

The Cretaceous in the Sacramento Valley area in northern California has yielded considerable gas, and shows of oil have been encountered in several of the wells drilled. This area has not yet been prospected thoroughly, and probably it will receive considerable attention from the oil companies in the future. Similarly, gas and shows of oil have been found in Pliocene beds along the coast near Eureka, 250 miles north of San Francisco. This region has not yet received adequate testing, though at present there is some activity in it.

### OTHER STATES

Many other States, including Washington, Oregon, the Dakotas, Nebraska, Arizona, Alabama, Georgia, and Florida, have witnessed recent activity, including geophysical investigations and drilling in the search for petroleum. In some areas the activity is based on surface seepages and shows of oil in wells, in other areas on apparently favorable structural conditions, and in others on the hope that favorable geologic conditions for oil not discernible at the surface or from geophysical surveys may be revealed by the drill. In none of these States has commercial production been developed.

## STATEMENT OF ALFRED G. WHITE, CHIEF ECONOMIST, PETROLEUM ECONOMICS DIVISION, BUREAU OF MINES

Mr. COLE. All right, Mr. White.

Mr. WHITE. Alfred G. White, chief economist, Petroleum Economics Division, Bureau of Mines.

I am a graduate of Lawrence College, of Appleton, Wis., with an A. B. degree; and an A. M. in economics from the University of Wisconsin, with 3 years graduate work at the Wharton School of Finance and Commerce, University of Pennsylvania.

I was economist for 6 years with the Bureau of Mines, from 1913 to 1919; from 1919 to 1929, professor of economic geography at the

Wharton School; and from 1929 to 1933 in charge of the competitive fuel studies for the National Industrial Conference Board of New York; author of a book entitled, "Oil Conservation and Fuel Oil Supply," and joint author of a book, "The Competitive Position of Coal in the United States."

Mr. MAPES. What is the date of those publications?

Mr. WHITE. 1930 to 1931. Published by the Conference Board at that time.

Mr. MAPES. How long has the Petroleum Economic Division of the Bureau of Mines been in existence?

Mr. WHITE. The collection of refinery statistics, I think, started about 1918, or possibly earlier than that. But the present division was the result of consolidation in about 1926, I think, and in 1935, of the work in the Department of Commerce relating to foreign trade in oil.

Mr. MAPES. You are the head of the Division?

Mr. WHITE. I have been head of that Division since April 1936.

Mr. MAPES. How big an organization have you?

Mr. WHITE. We have approximately 20 people in the Division, some 4 of them in the field and the balance in the Washington office.

The primary function of that Division is to make statistical and economical studies of the production, distribution, and consumption of crude petroleum and its products.

Mr. COLE. Doctor, may I ask you if you have copies of your statement?

Mr. WHITE. Two other members of my Division are presenting material on the motor-fuel situation or the world situation following me, so that I only have a very short statement, probably about three pages long, which covers the study that I want to present to the committee.

Mr. COLE. Who are the other two members of your Division?

Mr. WHITE. Mr. Breakey, on the motor-fuel situation, and Mr. Redfield, who has charge of our foreign and domestic trade petroleum studies.

Mr. COLE. All right.

Mr. WHITE. I have some things I want to briefly discuss that may not be discussed in their testimony.

Mr. COLE. Might I ask, Mr. White, if I may interrupt you again, is it rather a common practice for you to be lecturing throughout the country on the oil situation? I had occasion to hear you in one instance in California on this subject.

Mr. WHITE. I have not done much lecturing on the oil situation. I gave one lecture in connection with the Bureau of Mines series at the University of Maryland, and we carry on a certain amount of forecast work which is of interest to the interstate oil compact commission, and they generally ask me to their meetings to give them a discussion of the current trend of demand. Otherwise, I am not in the habit of generally lecturing on the subject.

Mr. COLE. Maybe I should say your work includes lecturing.

Mr. WHITE. Oh, yes.

Mr. MAPES. Our chairman is a regent of the University of Maryland.

Mr. WHITE. There are two subjects I want to very briefly discuss; one is the general trend since the last hearing before this committee of the growing demand for all oils. The details of certain refined products will be covered by Mr. Breakey later.

The total demand for all oils. as estimated for 1939—we have 9 months' statistics, and I am estimating for the other 3—will approximate 1,415,000,000 barrels and will represent an increase of about 380,000,000 barrels, or 37 percent. as compared with such demand in 1934.

Mr. MAPES. Right there, may I ask you a question? I am sorry to interrupt you, but I thought that the improved methods of converting the crude oil into the refined products were taking care of the increased demand. Your figures would indicate that is not true?

Mr. WHITE. Well, that depends on what type of products you consider as against the total production. As a matter of fact, the consumption of residual fuel oil probably is almost as high now as it was in 1929. Of course, the demand for gasoline and the yield of gasoline has been steadily increasing, but in the total demand you have taken care of the increased gasoline and the fuel distillates for house heating and for heavy fuel oil.

Now, during the depression the demand for heavy residual fuel oil, in company with the demand for coal, dropped off very materially. In other words, that was the main product that suffered during the depression. But that demand has been coming back and is very heavy at the present time.

But I should roughly say we are approaching about the same demand that we have had in the past. Now, the gasoline demand this year is far above any previous year, and the demand for light distillates for heating is far above what it has been in the past. And this consumption is a big consumption. It is an all-time peak consumption.

Mr. MAPES. The increase in the crude oil is going largely for gasoline; is that true?

Mr. WHITE. What we can say there——

Mr. MAPES. Your answer is not quite clear to me.

Mr. WHITE. Of course, if you go back far enough, to the time when the yield in gasoline was approximately 11 percent from crude oil, that is, back about 1910. During the World War years it went up quite rapidly, and since that time the progressive yield of gasoline has been going up, and I believe that the yield this year will be the maximum yield we have had for gasoline.

Mr. MAPES. I was going to ask you this: Within the last few weeks I saw some statement which led me to believe that it is possible now to refine the crude oil into almost any refined product that the refiner sees fit. Five years ago, as I recall it, he could only refine a certain amount of it into gasoline and a certain amount into fuel oil, and so on. Am I correct in that?

Mr. WHITE. That question really relates to Mr. Kreamer's report, which will come later, more than to mine. I can answer you approximately that these new processes give much more flexibility in getting the product you want. That is further illustrated by the fact that at the present time the gasoline yields may be around 30 to 32 percent in some districts and in others as high as 58 percent. And these new methods presumably may carry that flexibility further. But that will be discussed in more detail by Mr. Kreamer later.

Mr. WOLVERTON. Does that increase of 30 percent relate to domestic use or does it include foreign exportation as well?

Mr. WHITE. That is the demand for all oils. I was coming to the domestic demand a little later. That was an increase of 37 percent as compared to 1934 for the demand for all oils.

Now, our exports are the highest they have ever been. This year they will be about the same or just a little less than last year; we cannot tell yet.

But I was going to say that out of a total increase in distribution of 380,000,000 barrels since 1934, approximately 300,000,000 barrels were in the domestic demand and 80,000,000 barrels in exports. So that much of it has been an increase in the domestic demand.

Mr. WOLVERTON. What was the percentage of increase in foreign use?

Mr. WHITE. I have not figured that total out, but I can give you the approximate figures.

Mr. WOLVERTON. You gave us 380,000,000 barrels, which was an increase of 37 percent since 1934.

Mr. WHITE. Since 1934.

Mr. WOLVERTON. What percentage of increase does that 80,000,000 barrels for foreign use show?

Mr. WHITE. In answer, the total figure for the demand for all oils was 1,035,000,000 in 1934, so that 80,000,000 would be about 8 percent of that.

Mr. WOLVERTON. Yes; but what portion of that 1,100,000,000 barrels that you refer to in 1934 was foreign?

Mr. WHITE. Approximately 11 percent. It was 114,000,000 exported out of 1,035,000,000.

Mr. WOLVERTON. Then we have an increase of 80,000,000 on the 114,000,000; what percentage is that?

Mr. WHITE. You mean of the 114,000,000?

Mr. WOLVERTON. Yes. I thought that you could figure it quicker than I could.

Mr. WHITE. Well, it is close to two-thirds; I should say 66 percent, roughly.

Mr. WOLVERTON. So the increase in foreign demand has far exceeded the increase for domestic purposes.

Mr. WHITE. Relatively; of course, the increase has been greater.

Mr. WOLVERTON. I would say roughly that an increase of 80,000,000 over 114,000,000 is about 75 percent. You have given the general increase as 37 percent, so it would seem as if the increase, based on foreign demand, has been more than double the domestic rate of increase.

Mr. WHITE. Of course, that foreign export has been subject to a good deal of variation because, with the passage of the excise on imported oil, the tendency was for imports to drop, and for a time our exports dropped, as those former imports went to other markets. The peak of exports before this current year was in 1929, when we exported 163,000,000 barrels, and by 1934 that had dropped to about 115,000,000, and during the last 2 or 3 years it has been rapidly increasing to about 194,000,000.

Mr. WOLVERTON. What was the increase for the first 9 months of this present year, if you have it? Do you have the figures that show the increase?

Mr. WHITE. A slight decrease, if I recollect rightly. It will run very close this year, probably, to last year's figures, but some items dropped off.

The crude oil represents now a much larger factor in the exports than formerly, because of the development of refining in other countries. Our gasoline exports have been coming back, but the largest single item now is crude oil for foreign refining in foreign countries.

Mr. WOLVERTON. Has the amount of imports increased in proportion to the export demand?

Mr. WHITE. I am afraid that I am trespassing on Mr. Redfield's paper a little.

Mr. WOLVERTON. All right.

Mr. WHITE. But it has stayed very close since 1934. The average has been between fifty and fifty-five million barrels, sometimes a little lower and sometimes a little up. In other words, we are a larger exporter than an importer.

Mr. WOLVERTON. So, notwithstanding the very great increase in our own demands, we have not conserved our supply by increasing our imports.

Mr. WHITE. Neither by increasing our imports or decreasing our exports.

Mr. MAPES. I wish you would deal with it in a little more definite way, perhaps in nontechnical language, so that we can understand how much of the refined product has been taken care of by the improvement in the refining process without any increase of crude oil.

Mr. WHITE. The fundamental thing that has kept the amount of crude oil down to as low a figure as it has been is the increase in gasoline yield.

Mr. MAPES. Increase through the refining process?

Mr. WHITE. That has been due in the past to what is called cracking, by the addition of heat and pressure to break up the heavier parts of the oil into lighter parts.

Mr. MAPES. Has this cracking process made it possible to take care of the increased demands for gasoline without consuming much additional crude oil?

Mr. WHITE. That depends on the extent to which the oil industry finds it profitable to market the heavy fuel oils and the lighter heating oils. Apparently at the present time it has.

Mr. MAPES. Why should not the industry be able to take care of the demands for gasoline without any reference to the fuel-oil end of it?

Mr. WHITE. That is purely a question of what the profit on the refined oil is. It is profitable to make light-oil distillates, the heating oils, and consumption in that line has very rapidly gone up.

Now, that represents approximately a yield of 13 percent of the crude, whereas 10 or 15 years ago it was a very minor factor.

Mr. MAPES. Assuming that it takes crude oil to take care of that fuel oil, my question is, Does the cracking process and the improved methods of refining take care of the increase in gasoline demands without any increase in crude oil?

Mr. WHITE. I think that is really a subject that Mr. Kreamer ought to discuss.

Mr. MAPES. Do I make myself clear?

Mr. WHITE. Yes; I think I understand your question. Your question is why should we keep on refining larger and larger quantities of crude if we can make more gasoline without increasing the crude refined.

Mr. MAPES. Of course, that only applies to the gasoline part of it. It may be that you need more crude oil for other things.

I wonder if I am correct in my understanding of that, so far as gasoline is concerned.

Mr. WHITE. Some 26 percent of the crude oil refined is classified as residual fuel oil and competes with coal, and parts of that at least might, under usual and normal conditions, be converted further into higher-grade products.

Mr. MAPES. My question is confined to the gasoline end.

Mr. WHITE. Well, as I gathered, your question related to whether we could supply our gasoline requirements without using any more or as much crude oil as we do now.

Mr. MAPES. Yes.

Mr. WHITE. I think we could.

Mr. MAPES. We do supply our gasoline requirements now without using any more crude oil than we did 2, 3, 4, or 5 years ago. Is that correct?

Mr. WHITE. Well, I would like to let that question go over to the refinery experts of the Bureau of Mines, who will be here later.

Mr. MAPES. All right.

Mr. WHITE. After a decrease of about 1 percent in the demand for all oils in 1938 as compared to 1937, the current year promises to show an increase of about 6.5 percent over 1938, or roughly 5½ percent over the previous peak of demand for oil in 1937. In other words, 1939 is the all-time peak of the total demand for oil production in the United States, including domestic and export.

Mr. COLE. Mr. White, do you have any figures as to what the percentage increase in demand would be in case of a war?

Mr. WHITE. Well, I have been reading practically all of the estimates that appear, and there are two parts to that question—the domestic situation and the foreign situation. And the various foreign estimates of major countries range all the way, the estimates, from a 50-percent increase to sixfold, some of which I personally consider as ridiculous estimates.

Mr. COLE. Ridiculously high?

Mr. WHITE. In other words, the total demand in most major countries for oil has increased to such an extent that the relation of military requirements to that total demand must be possibly much less than in the World War period. In other words, we know that we are consuming so much more gasoline that any possible diversion of gasoline would be a comparatively minor factor as compared to the total consumption. Present consumption is 10 or 11 times what it was in the World War period. That, I think, has been overlooked in most of these estimates, and there is a very severe system of rationing which has been put into effect in almost every European country, for at least the time being, which may curtail last year's requirements by 25 to 30 percent.

Now, they are conserving their stocks until the transportation situation is straightened out. Whether they will relax remains to be seen. Of course, some of these uses undoubtedly will have to continue, but you have a 75-percent cut in gasoline used by private automobiles in Great Britain, for the time being, and they may maintain at least a part of that for a considerable period.

Now, we have been very carefully checking up on all export estimates from this country insofar as our October and November situation is concerned, and expect very shortly to check the December situation. We can find yet little evidence of much larger exports than in the last quarter of last year. They were very high in that quarter and included some military stocking; but when the demand is going to materialize and how large it is going to be is a question. I should say roughly that it varies and that conservative estimates range from 10 to 25 percent possible increase in total demands for oil in this country. I lean more to the lower estimate myself. Because of exchange and other conditions quite a bit of oil will be secured from other parts of the British Empire. And, possibly, the most significant thing will be what our own increase in domestic demand will be stimulated by the improvement in industrial conditions. I think that Mr. Redfield will be in a position to comment on the other sources of oil that are now available. In other words, in other parts of the world.

In the World War situation there were not nearly as many sources of oil supply available in other parts of the world, and, of course, the distance of transport is quite a problem; but you have a larger tanker capacity in the world at the present time, and it is so large that they had a world tanker pool to take care of idle tankers. They abolished that just about the time the war broke out as no longer necessary. But, the world has a pretty large tanker capacity, and the question of moving oils may or may not become a difficult one. It does not appear to be any immediate problem one way or the other.

But, the whole matter is speculative and we have seen so far no evidence of the maximum possible increase. My own guess is that an increase of around 10 percent might very well take care of any requirements in the next 5, 6, or 7 months. I may be wrong. It may require more than that. On the other hand, my guess of the requirements may be too high. It is just one of those speculative things, but it is absolutely impossible, I should say, to have any severalfold increase in demand from any European country considering purchases and exchange conditions, transportation conditions, and the large amount of normal consumption that could be diverted to war requirements by rationing and curtailing consumption.

Now, those are just my own views as a result of a very careful study of all estimates that have been made and that have been available from different sources.

That finishes practically what I wanted to say on the general picture of the relation of demand at the present time to the 1934 situation.

I have one other subject that I want to very briefly discuss, and that is the relation of the stocks of all oils to demand.

The problem of stocks has been one that has been ever present in the oil industry and caused a good deal of disruption in marketing and price conditions, particularly in the last year or year and a half, and I think it desirable very briefly to review the trend of the total stock situation since 1934.

Mr. Wolverton. Will you define what you mean by "stocks."

Mr. White. The stocks of all oil held in this country, crude and refined. I will make some distinctions between the crudes and refined in the discussion, but that is the total available amount of oil in storage as of the beginning of the year or periods I indicate.

I began by starting with January 1, 1934, and comparing the situation with the current stock situation. We must keep in mind in the meantime demand as I have indicated, total demand, for all oil has increased about 37 percent in that period and now it seems to me a very brief review of the total amount of stocks on hand in relation to the demand will be desirable.

On January 1, 1934, the stocks of all oils in the United States were 603,000,000 barrels, or approximately 7 months' supply in terms of 1934 total demand. The stock at the beginning year, in terms of that year's demand, would have supplied 7 months of the average demand of that year.

On January 1, 1939, the stocks of all oils had been reduced to 556,000,000 barrels, or about 4.7 months' supply in terms of estimated demand for 1939. Of course, in terms of month's supply that reduction is partly due to increase in demand and partly due to reduction in total stocks. So that, roughly, stocks based on the year's demand have shrunk from 7 months in 1934 to 4.7 months in 1939.

Mr. Wolverton. Did the shut-down of production in August for a period of time have any effect on that?

Mr. White. Not on the period prior to January 1, 1939. It will on the figures that I am going to mention later, for the end of August.

Roughly that shut-down probably caused a reduction of 30,000,000 barrels in crude-oil stocks. Some reduction might have taken place without it, but the actual stocks of crude oil went down in August, I think, by 32,000,000 barrels, and most of that was probably due to that shut-down, but part of it probably would have taken place anyway; but roughly speaking the production holiday probably further cut the stocks of crude oil by close to 30,000,000 barrels. I was just coming to that. By that time, August 31, 1939, stocks of all oil were further reduced to 522,000,000 barrels; that is, from 556,000,000 barrels on January 1, 1939. There was about a 34,000,000-barrel decrease from the beginning of the year until the end of August, through the production holiday, and most of that was crude.

Mr. Mapes. Have you any comment to make on the argument of some, that in times past the major companies underestimated the amount of petroleum in the ground and put an unreasonable amount in storage and that they now want to get rid of that amount of storage so they advocate restriction of production and conservation to enable them to get a higher price for the oil they have in storage?

Mr. White. I would rather put that on a different basis. I should say that the available reserves in the ground that can be turned into produution at a moment's notice has made unnecessary as large a stock above ground as was formerly the case. That is, you can draw on several billion barrels, at very short notice, of these shut-in reserves, and many of them shut down to the point where they could very easily be expanded. It is obvious you need less oil above ground, certainly crude, if you can get it any time you want it.

Mr. Mapes. I said that that was the statement or argument of some, as I understood it.

Mr. White. I have no knowledge of the policy of the individual companies in that connection. I was just suggesting a very sound economic reason for such a policy and when you get oil above ground it is more readily subject to taxation possibly than if you have it below ground, where the amount of it is somewhat uncertain.

Mr. Mapes. In your judgment, what is a reasonable amount to have in storage?

Mr. White. I think that will be answered by the very short page and a half that I still have in the report that I want to present.

The decline in all stocks from January 1, 1934, to August 31, 1939, that is, the latest current figures we have to cover the period since the first of 1934, represents a total decrease of approximately 81,000,000 barrels, consisting of a decrease of 116,000,000 in refinable crude stocks and an increase of about 35,000,000 in stocks of refined products which includes small amounts of natural gasoline and certain amounts of heavy crude in California which we have just recently segregated from fuel oil; but, roughly speaking, the total decline then of 81,000,000 barrels of stocks in that period is a decline of 116,000,000 barrels in refinable crude and another 35,000,000 increase in refined products which together makes a decrease of 81,000,000.

As of June 30, 1936, the Bureau of Mines conducted a survey of crude oil in storage. Briefly, the conclusions reached were that minimum stocks of refinable crude oil would approximate 205,000,000 barrels, including working stocks and about 6 weeks' refinery supply. In other words, we estimate that 205,000,000 barrels was about as low as crude stocks could go. We did not say that they should go that low, but as low as they probably could go and take care of the working requirements, including 6 weeks' supply for refineries.

Actual desirable levels for crude stocks might range from the minimum of 205,000,000 barrels to about 250,000,000, depending on individual company positions and the amount of old accumulations of surplus stocks not in active liquidation. That is stocks which have been accumulated which are simply lying dormant and are not in the available working supply to the industry. They are held by a few companies, and they may liquidate them sometime. If they are not liquidated, they should be added to the total amount, and we figured therefore that the absolute minimum was about 205,000,000 for refinable crude and, considering a certain amount of these old stocks and certain company positions, it indicated that a minimum of 250,000,000 barrels might be required. In other words, crude-oil stocks anywhere from between 205,000,000 and 250,000,000 then might represent a reasonable level of crude-oil stocks, considering the present availability of large quantities of shut-in oil.

Now, currently, the total refinable crude stocks have been reduced to about 230,000,000 barrels. That is a little later than the August 31 figure. That is about the current figure at the present time. In other words, stocks are down to somewhere between these two figures that the Bureau was estimating.

In my opinion, since this figure includes considerable recent accumulations of surplus stocks in California as well as some remainders of old stock accumulations east of California, the present level of total refinable crude stocks is between the minimums represented in the results of the Bureau of Mines survey, and is probably very close to the actual working minimum, and raises the question of whether it would be desirable to go any further in the reduction of crude-oil stocks.

In view of the current large demand for refined products, stocks of refined oils are probably not excessive as a whole.

Mr. MAPES. May I interrupt you there?

Mr. WHITE. Yes, sir.

Mr. MAPES. If the industry is running on the minimum of crude in stocks, unless it is refining more than the consumers want, there is not any overproduction in the country, is there?

Mr. WHITE. You mean, if your stocks are not building up? Of course, the peculiar problem there is that the refining end of the industry may be refining more oil than there is any need for.

Mr. MAPES. Well, it will have to be disposed of to the consumers, or by putting it in storage.

Mr. WHITE. And that is why I was just coming to a brief discussion of refined stocks, indicating whether there was an excessive situation in refined stocks. If not, the conclusion is that the industry has largely wiped out excessive stocks accumulated by the depression and the opening of the east Texas and other fields. As a whole, with one or two exceptions, the stock situation has been reduced very close to reasonable minimums in the present situation, which is quite different than the conditions that were existing on January 1, 1934, when excessive accumulations in respect to demand were on hand.

Mr. MAPES. If your conclusion in that respect is true, if there is any waste in the industry, it is in the method of production. Is that correct?

Mr. WHITE. That is a logical construction, except that you must consider whether conditions are apt to occur which might cause further accumulations of unnecessary flush oil and you might have this problem recurring, otherwise the conclusion is sound.

Mr. MAPES. Unless we anticipate some condition in the future that does not now exist?

Mr. WHITE. I just have about two paragraphs more and I think I will cover both of those points. Rather than risk the danger of repeating them, I will finish what I have to say on that subject.

In view of the current large demand for refined products, stocks of refined oils are probably not excessive as a whole, although a material surplus in seasonable gasoline stocks exists in both California and in the district east of California and a material surplus of residual fuel-oil stocks exists in California. In other words, California has more of the clearly excess stocks than the East, where stocks as a whole are in very reasonable balance with the trend of demands.

In 1937 finished gasoline stocks rose by 13½ million barrels, in the face of what proved to be practically a stationary market. In other words, you had nearly 13½ million barrels more gasoline stocks, with the same demand, practically, as in 1937, and obviously there was an unnecessary accumulation to almost that extent.

Now, in 1938 they reduced that excess by 4,000,000 barrels and, with improving demand at the present time and prospects of further improvement in demand, part of that surplus which has caused so much disturbance may be wiped out. It is still a matter of very considerable concern, this question of possible excess gasoline stocks to the industry.

There are various estimates of how excessive gasoline stocks are and, of course, if a large export demand does materialize, those excess stocks may be wiped out, but if a large export demand does not materialize, the industry may end up the winter season with obviously too much gasoline stock. That depends on the trend of demand this winter.

I may say in that connection that runs to stills, refinery operations, are the highest in recent months they have ever been. They reached a maximum peak of refinery operations in anticipation of increased domestic and foreign demands, which if it materializes may warrant the operations, but if it does not materialize, the refining end of the industry may accumulate excessive stocks.

There is no question but what the refineries could meet any demand that is likely to come up in the course of the next 6 or 12 months without any trouble.

It should be borne in mind that the present large underground reserves or shut-in crude production make additional supplies quickly available and therefore tend to reduce the necessary amount of aboveground stocks.

Authorities generally agree that any current requirements during the next 3 to 6 months, or even a year, that are apt to materialize can be readily met either from surface stocks or from underground reserves.

That goes back, I think, to the question that was raised before of our 14 to 17 billion barrels of surplus reserves. I think Colonel Thompson's statement was largely concerned with the fact that if you were anticipating war demands, both for the domestic situation and possibly for military exports, that we have plenty of reserves to meet any demand in the next year or two. It was not a question of a long-period set-up, but of sufficient oil to meet any conceivable requirements in the near future and with probably plenty of refinery capacity to handle it.

In conclusion, it appears that material progress has been made in the elimination of wasteful storage resulting from past surplus production. Any recurrence of this problem would depend upon uncontrolled flush production from new major fields.

That is the end of the very brief statement that I have prepared.

Mr. Mapes. May I ask you if you have made any study of that which has been referred to as unfair practices and unfair competitive practices in the industry?

Mr. White. I consider questions of that kind as beyond the scope of the Bureau of Mines' functions, which is to collect facts and present them in unbiased reports, and obviously we deal with the industry on a voluntary cooperative basis and are primarily dealing with economic data, rather than practices or theories.

Mr. Mapes. Do you care to express an opinion as to whether the Administrator under the terms of this bill, if enacted into law, would be given authority to correct those unfair practices, if such exist?

Mr. White. I am not in a position to comment on the bill, the purpose of which, primarily, as I understand it, is the maintenance of engineering practices in the production of crude. It does not deal with, as I understand it, the question of market demands or relation of marketing to production. It is primarily related to production and outside of the possible effect on the work which we are doing, I have not made a serious study of the bill in question.

Mr. MAPES. Do you take it that it will enable the Administrator to consider the questions raised by the complaints of the retailers and jobbers, the independent refiners, and the separation of pipe lines from the rest of the industry?

Mr. WHITE. It is my understanding that the Commission established in the bill itself only deals with production of crude oil, where it is evidently being produced by methods which do not lead to the greatest conservation and largest output of oil. I do not think, from my own examination of the bill, that it covers other problems.

Of course, I am not qualified to speak as to what the intent or exact covering would be in that case.

Mr. MAPES. I wonder if the major complaints now were not those that I have referred to rather than the wasteful production.

Mr. WHITE. I think you will find this same set of complaints in any industry which represents groups of independent producers and refiners, and of large integrated companies. It is more or less a common problem in any industry which contains those different groups of individual organizations. I do not know that it is peculiar to the oil industry.

Mr. MAPES. In other words, one branch of the industry criticizes another branch, and so on.

Mr. WHITE. That is a very logical situation.

Mr. WOLVERTON. Mr. Chairman.

Mr. COLE. Mr. Wolverton.

Mr. WOLVERTON. You say that the bill, in your opinion, relates to the subject of production.

Mr. WHITE. Yes, sir.

Mr. WOLVERTON. Would you say, as an economist, that limitation of production has a direct effect on the price charged to the consumer?

Mr. WHITE. Undoubtedly limitation of production would have an effect on price, in my opinion. Of course the effect might be to raise prices, or to stabilize prices, or to prevent the decrease in prices, either one.

Mr. WOLVERTON. In other words, production does have a direct relation to price.

Mr. WHITE. The quantity of production would have, I should say, a direct relation to price.

Mr. WOLVERTON. In view of the fact that conservation has been given as a basis for all of this type of legislation that we have passed, I was very much interested in the action that was taken last August by the several States which were parties to the compact agreement, when there was action by a company that reduced prices. The oil-producing States, or some of them, immediately stopped production.

Was there any relationship between the stopping of production to prices, or was it based on the need of conservation?

Mr. WHITE. I think I should have added to my statement that the reduction of production would affect prices provided there were not sufficient stocks to cushion any such action. In other words, you cannot take production by itself. You have got to take a relationship between production and stocks. If you assume that limited relationship, either limited stocks or limited production, then you will have an effect undoubtedly on the price situation.

Mr. Wolverton. I am speaking of it in that more general sense.

Mr. White. Yes.

Mr. Wolverton. Your stocks will naturally reflect production and over a long range of time they have a direct relationship to it. It could not be otherwise, in my opinion.

Can you tell me as an economist what excuse could be offered from a conservation standpoint for the shutting off of all production because one company had reduced its price to the consumers?

Mr. White. Well, I think when you limit it to one company that that would be an error, because if prices broke in any field you would have a general break in prices following and that as I think is indicated in this last situation. Of course——

Mr. Wolverton. Well, that was a question of stabilization and not conservation; was it not?

Mr. White. I should assume that it was a question of stabilization.

Mr. Wolverton. Well, that is the theory that I have had in my mind very frequently during these years in which we have given consideration to this subject, that, while it was asked for in the name of conservation, the real purpose to be attained was stabilization; and I have thought that some of the oil-States have proved the case by their recent action, by the action of several States last August, when to offset a possible general decrease in price, they immediately shut off all of the wells.

Now, if we are going to pass this kind of legislation for stabilization purposes, let us know it; if we are going to pass it for conservation purposes, let us know it; but I do not like to be a party to doing something on the basis of a high motive such as conservation and find that basically it is for some other purpose, namely, stabilization.

Mr. White. I do not think it is safe to assume that stabilization has no relation to conservation. Where you have a varied production from wells of all sorts and conditions and costs, you may very well have a price level which goes so low that you may abandon very considerable parts of production, or you may lower the price so that the competitive fuel oils may extend in the fuel market and produce an uneconomic use of oil which ought to be reserved for higher production. In other words, there is another factor in stabilization. Also, stabilization, if you are speaking of it in relation of supply to demand, may relate to the accumulation of excess stocks.

It seems to me, and I would like to broaden the idea, that the term "stabilization" in an industry has other relations besides a price factor. They do have a relation to conservation in various angles.

Mr. Wolverton. Well, I do not see anything in the effort last August, except to stop oil being sold by one company cheaper than the "regulars" thought it should be sold. Maybe they had that fine idealistic thought behind their action that your answer indicates.

Mr. White. Let me make it clear the Bureau of Mines makes forecasts of market demands for crude oil. We attempt to project what the normal demand is going to be for gasoline and for crude. We do not indicate whether it should come from stocks or new production. We stop at that point.

The question of whether you want to cut stocks for stabilization or other purposes is primarily a matter of policy by anybody who has authority—State or Federal—in the oil situation. Therefore, the questions you are asking me are policy questions of the agencies to whom we may furnish information.

Mr. Wolverton. Well, prior to the action of August the only basis that I have seen controlling the amount produced was the estimate of supply and demand, as fixed by regulation of State regulatory bodies assisted by Government agencies; but that was not the case in August. They did not say that the demand was too great. They said that the price was too low, "and we will bring them to terms"; and they evidently did.

It does not seem to me that it admits of any argument as to what was the real purpose in the action that was taken.

Now, what happens when the stocks are greater than might be necessary to meet demands? What happens from the consumer's standpoint?

Mr. White. Of course, when stocks are excessive, you usually have a condition of a run-away production from new fields. I was down in Oklahoma at the time the Cushing field was at its height, where you saw oil stored in all sorts of earthen tanks. In fact, the Cushing field came in at the end of 1914 and the beginning of 1915 and so obscured the production-and-demand situation that we could hardly tell what was the effect of the World War on oil demands. It added a tremendous supply with lower prices. Whether the price reduction was due to stagnation in the early stages of the war or excess production of the Cushing field was hard to determine.

It seems to me your question of excessive stocks depends entirely on what the production conditions are and its relation to conservation depends largely on the question of whether you bring large amounts of unneeded oil to the surface, storing it under wasteful conditions, and subject to the greatest loss of the lightest fraction of gasoline.

Mr. Wolverton. Well, when you have a larger stock than immediate demand requires, what happens to it? Is it wasted?

Mr. White. You hold it in storage, and costly storage, which certainly means a financial waste to whoever holds it, or you sell it at prices which may be entirely inadequate to meet the cost of production and refining.

Mr. Wolverton. Now, as to your first reason, as to the cost of storage, that is a problem that the individual company that has it in storage must deal with, and I am not concerned with that so much.

Your second reason, as given by you, was that it would result in a break of prices. Now, we come right back again to the question of stabilization of prices, which seems to me again proves that after all this type of legislation has in mind the stabilization of prices as much or more than it does conservation.

Mr. White. Well, I am in no position, nor would any economist be, to argue that if you decrease supply that does not have some relation to prices. And any discussion of prices in industry, it seems to me, would have to be based on two factors—long-term trend of prices and their reasonableness. There may be no advantage gained from short-term breaks in prices to the consumer. There are a great variety of factors involved, especially if you add the fact that you are dealing with a commodity whose total supply is much more limited than any other major commodity used in such enormous quantities.

The major consideration in our reserves, to my mind, is the fact of our enormous consumption. When you get up to 1,400,000,000 barrels—and it will probably be 1,500,000,000 next year—you have such an enormous quantity that you cannot rely on substitute sources at higher costs under present conditions. If supplies should diminish to a comparatively small degree, say, 10 or 15 percent, it might double prices in the industry. We have had periods of shortage in oil when the prices of crude have gone to $3.07 a barrel, and then more oil was brought out and the market broke to 65 cents.

In other words, the real argument, which I am in no position to follow, rests more on the long-term price trends and the question as to whether they are justifiable.

Certainly if you measure the price of crude oil per barrel at the well for the last 20 or 25 years, you will find that it has broken only two or three times to the level of 60 to 70 cents per barrel, and under extreme conditions.

The real question at issue is whether prices ranging from 97 cents to $1.18 since 1934, average yearly prices, represent any undue harm to the consumer of oil or whether he has any right to expect oil at cheaper prices than that, and whether, if you did not keep those prices at about that level, you would not lose enough production by closing in of marginal wells to probably very shortly raise the price to the consumer. I am just suggesting the line of thought I would follow if I were going to appraise the question of the reasonableness or unreasonableness of the price of crude. I am in no position to discuss that. It is hardly my function. But I have given thought to it, and it seems to me that it is a fair consideration in any factor of control that relates to price as to whether on the average it is going to create a price which is unreasonable. There is no question whatever in my mind that price is a significant factor in the conservation of oil. If prices are too low, you will get waste in production and you will have more oil consumed in competition with coal and other fuels than is desirable.

I do not know of any other major product whose supply in terms of years' supply is as limited and dependent on new exploration and discovery. We are withdrawing a billion and a half barrels of oil production a year from the reserves that we are talking about. Even though those reserves may be increased, it is obvious that we are dealing with a total supply which is small as compared with the enormous rates of consumption, and that if new discoveries should fail, we will undoubtedly pay two or three times the price that we are paying for oil at the present time.

Mr. Wolverton. The answer that you have given has stated as well as any I have heard in the past 5 years a justification of this legislation from the standpoint of stabilization; but, so far as I am concerned, it seems the emphasis that is placed on conservation is, to some extent, a cover for stabilization and the necessity for stabilization of price you have set forth; but when you speak of a natural resource that is being depleted—and we are told over the radio in very dramatic fashion and by a prearranged story of a doctor receiving a call, which he could not answer because Bobby at the gasoline station said there was no more gas, as the eventual thing that will happen if we do not have conservation. It strikes me that is going a long ways to show the need of conservation as a basis for stabilization of prices.

You spoke of and laid emphasis upon the stocks being greater than demand. I am trying to find out just how far that results in waste. Suppose there are 100,000,000 more barrels than you think is necessary. Suppose there are 500,000,000 instead of 205,000,000 that you think is necessary. What happens? Is that wasted? I have never seen any running loose.

Mr. WHITE. Of course, your question of waste relates primarily, I take it, to physical waste of the oil itself.

Mr. WOLVERTON. Well, I think——

Mr. WHITE (interposing). The cost of unnecessarily keeping things in storage must be passed on to the consumer, I should say, or be a loss to the owner of it, one of the two.

Mr. WOLVERTON. But there is no waste in the sense that it is not used.

Mr. WHITE. That is why I was asking the question. I would call that economic waste, not physical waste.

Mr. WOLVERTON. That is just what I wanted to bring out. Does this bill deal with physical waste or economic waste?

Mr. WHITE. I think the bill answers that question itself, if I recollect, in its language.

Mr. WOLVERTON. Physical waste?

Mr. WHITE. It has no relation to balancing market demand and supply, so far as I can find out.

Mr. WOLVERTON. Well, some of the articles I have read indicate that in the opinion of some that it is leading up to an economic control and not stopping at a physical control of waste.

Mr. WHITE. Well, that is a matter that I do not feel competent to discuss.

Mr. WOLVERTON. I am asking the question because of the fact that it is in the mind of some individuals, if we are to judge by expressions in public meetings and articles that they have written and that have appeared in magazines.

Mr. WHITE. Very frankly, from my point of view, which is purely economic and relates primarily to consumption and the balance of the industry, I feel that an unstable and excessive stock condition is injurious to the producers and the consumers of oil as well and that constant fluctuations of the price, up and down, one year paying $2 a barrel, and the next year paying 65 cents a barrel, is not a sound or stable situation so far as the consumer is concerned.

Mr. WOLVERTON. Nor is it any different from any other industry that produces too much and has a surplus stock.

Mr. WHITE. Well, that is a parallel in a great many other industries.

Mr. WOLVERTON. Yes.

Mr. White. As in agriculture or manufacturing, and it seems to me that is the point of view that I take of the stock situation.

Mr. Wolverton. The only reason that you might be given for this kind of legislation with respect to oil, and not apply to any other manufactured product, is the fact that oil is a natural resource, and as stated, there is a limited supply? I assume that that might be a reason from the standpoint of conservation.

Mr. White. I am not in a position to give reasons for the present legislation. I am trying to indicate, so far as our factual data goes, the information along certain lines. As soon as you get into the question of policy and purposes of the bill, that is obviously a question for the persons to answer who have prepared the bill and who are advocating the bill.

Mr. Wolverton. Of course, you recognize that it is the duty of this committee to determine the advisability of the legislation from the standpoint of policies, purposes, and objectives, and so forth. That is the reason I think that maybe my questions have taken a broad field.

Mr. White. I appreciate that, but it gets somewhat beyond the line of my particular work, and I do not like to express for other people what their ideas may be or even what I think they may be.

Mr. Cole. Is that all?

Mr. Mapes. You have spoken about various prices for crude oil. I understand that a variation of 25 cents a barrel for crude oil, approximately, means a difference of about 1 cent in the price of gasoline.

How would that variation affect the price of fuel oil?

Mr. White. That depends entirely on the circumstances. I was comparing, the other day, the price of bunker C oil at New York Harbor to the average price of crude at the wells over a series of years. At times the price of bunker C oil would be considerably above the average price of crude at the well, which would be expected, because there are transportation costs to New York Harbor included. And, at other times it would be considerably below. In other words, the price of fuel oil on the average did not exceed the price of crude at the well. Of course, in refineries near crude production it oftentimes is much less. It is a byproduct, industrially, which depends more on conditions in the competitive fuel market than it does on the price of oil.

Mr. Mapes. Take the oil that is used in the heating of homes.

Mr. White. Well, that is another matter entirely. That is a preferential product and is worth at the refinery not as much as gasoline, but more nearly approximates it. It is a product which may sell for 3 to 3½ cents at the refinery in comparison with maybe 5 or 5½ cents for gasoline. In other words, it is becoming a preferential profit product in the industry whereas the heavy fuel oil is not.

Probably the same principle would hold for the lighter heating oils that holds for gasoline. Any increased cost per barrel of raw material would have to be passed on to that particular commodity. It has to show a profit. It is one of the profit factors, and you have to pass the cost on, or pass on at least that much proportionately.

Mr. **Mapes**. Would it have about the same relation to the price of crude as it does to gasoline?

Mr. **White**. Well, of course, not quite the same relationship, because your percentage of oil so used is different. The ratio of gasoline is primarily based on the yield of something like 44 percent. Now, for these light distillates the total yield for the year is only about 13 percent. It may be increased as time goes on, but it is now less than a third of the volume of gasoline, so that if you are thinking in terms of the cost of crude, it depends on the relative amount of production you use to base that increase on. If you are going to base it in part on gasoline, and in part on distillates, it would not be the same. Under ordinary conditions you would not base it so much on residual fuel oil because it competes with coal and its market is partly dependent upon the cost of coal and other sources of fuel and power.

Mr. **Mapes**. The price of crude oil would have to be quite materially increased to increase substantially the price of fuel oil used in the ordinary burner to heat a home?

Mr. **White**. I should say that would be true, without any question, and with larger yields of that particular product from a barrel of crude, which increases the relative profit on the barrel of crude, it would make it necessary to pass less of such increased cost to each unit of output.

Mr. **Mapes**. Mr. White, do you think that there will be an increased, further demand for crude-oil production during the next few months in view of the present world situation?

Mr. **White**. I think possibly, particularly as regards the possibility of expansion of foreign sources, that that may be a subject that Mr. Redfield will take up.

So far as any question of general expectation of increased demands, that is another factor. If you are interested in the question of the development in foreign countries, and how they may expand their output to take a part of any increase. I think Mr. Redfield can give you the conditions in the major producing countries in the world, indicating to what extent they might materially increase their output to meet a part of these requirements.

I think in our previous discussion I indicated the varied character of the estimates that have been made as to total increased demands, and my opinion is that those totals should be treated at the present time very conservatively; that we have no evidence of any such large increase as some people contemplate. If you are interested in the details as to what other countries can do, I think that Mr. Redfield is much better qualified than I am and can discuss the current conditions in the other producing countries.

Mr. **Cole**. All right, sir. Are there any further questions? If not, we thank you.

Mr. **White**. May I add, Mr. Cole, I have attached to my paper, which I will file for the record, a table showing the supply and demand of all oils from 1918 to 1938, inclusive, which I would like to put in at the end of my testimony.

Mr. **Cole**. Very well.

(The table referred to is as follows:)

*United States supply and demand of all oils, 1918–38*

[Millions of barrels]

| Year | Crude production | Production, natural gasoline and benzol | Total imports | New supply | Change stocks, all oils | Total demand, all oils | Domestic demand | Total exports [1] |
|---|---|---|---|---|---|---|---|---|
| 1918 | 355. 9 | 8. 0 | 39. 0 | 402. 9 | −24. 5 | 427. 4 | 359. 4 | 68. 0 |
| 1919 | 378. 4 | 9. 8 | 54. 2 | 442. 4 | +4. 1 | 438. 3 | 374. 5 | 63. 8 |
| 1920 | 442. 9 | 11. 0 | 108. 8 | 562. 7 | +27. 3 | 535. 4 | 455. 8 | 79. 6 |
| 1921 | 472. 2 | 12. 1 | 128. 8 | 613. 1 | +84. 6 | 528. 5 | 456. 8 | 71. 7 |
| 1922 | 557. 5 | 13. 7 | 136. 0 | 707. 2 | +102. 0 | 605. 2 | 530. 9 | 74. 3 |
| 1923 | 732. 4 | 21. 8 | 99. 7 | 853. 9 | +99. 5 | 752. 4 | 652. 4 | 102. 0 |
| 1924 | 713. 9 | 24. 4 | 94. 6 | 832. 9 | +27. 9 | 805. 0 | 687. 9 | 117. 1 |
| 1925 | 763. 7 | 28. 2 | 78. 2 | 870. 1 | +29. 3 | 840. 8 | 727. 0 | 113. 8 |
| 1926 | 770. 9 | 34. 4 | 81. 3 | 886. 6 | −26. 4 | 913. 0 | 781. 1 | 131. 9 |
| 1927 | 901. 1 | 41. 2 | 71. 8 | 1, 014. 1 | +70. 1 | 944. 0 | 803. 0 | 141. 0 |
| 1928 | 901. 5 | 45. 1 | 91. 6 | 1, 038. 2 | +22. 8 | 1, 015. 4 | 860. 4 | 155. 0 |
| 1929 | 1, 007. 3 | 55. 3 | 108. 7 | 1, 171. 3 | +68. 1 | 1, 103. 2 | 940. 1 | 163. 1 |
| 1930 | 898. 0 | 55. 3 | 105. 6 | 1, 058. 9 | −24. 0 | 1, 082. 9 | 926. 4 | 156. 5 |
| 1931 | 851. 1 | 45. 4 | 86. 1 | 982. 6 | −45. 0 | 1, 027. 6 | 903. 2 | 124. 4 |
| 1932 | 785. 2 | 37. 3 | 74. 5 | 897. 0 | −41. 8 | 938. 8 | 835. 5 | 103. 3 |
| 1933 | 905. 7 | 35. 2 | 45. 3 | 986. 2 | +11. 0 | 975. 2 | 868. 5 | 106. 7 |
| 1934 | 908. 1 | 38. 3 | 50. 5 | 996. 9 | −37. 8 | 1, 034. 7 | 920. 2 | 114. 5 |
| 1935 | 996. 6 | 41. 2 | 52. 6 | 1, 090. 4 | −22. 3 | 1, 112. 7 | 983. 7 | 129. 0 |
| 1936 | 1, 099. 7 | 45. 3 | 57. 1 | 1, 202. 1 | −22. 7 | 1, 224. 7 | 1, 092. 7 | 132. 0 |
| 1937 | 1, 279. 1 | 52. 0 | 57. 2 | 1, 388. 3 | +45. 8 | 1, 342. 5 | 1, 169. 7 | 172. 8 |
| 1938 [2] | 1, 214. 4 | 53. 1 | 54. 3 | 1, 321. 8 | −9. 1 | 1, 330. 9 | 1, 137. 1 | 193. 8 |

[1] Includes shipments to noncontiguous territories.

[2] Final figures.

Mr. COLE. I would like for the witnesses to revise their testimony as quickly was possible, because some members of the committee wish to leave town pretty soon. We hope to have this testimony printed this week.

The committee will stand adjourned until 10:30 o'clock tomorrow morning.

(Thereupon, at 4:30 p. m., the committee adjourned to meet the following morning, Tuesday, November 7, 1939, at 10:30 a. m.)

# PETROLEUM INVESTIGATION

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TUESDAY, NOVEMBER 7, 1939

House of Representatives,
Subcommittee of the Committee on
Interstate and Foreign Commerce,
*Washington, D. C.*

The subcommittee met, pursuant to adjournment, at 10:30 a. m., in the committee room, New House Office Building, Hon. William P. Cole, Jr., presiding.

Mr. Cole. The committee will please come to order.

We will hear you, Dr. Breakey.

## STATEMENT OF H. A. BREAKEY, PETROLEUM ECONOMICS DIVISION, BUREAU OF MINES, DEPARTMENT OF THE INTERIOR

Mr. Cole. Mr. Breakey, for the record, will you give your full name and position?

Mr. Breakey. H. A. Breakey. For the past 9 years I have been with the Petroleum Economics Division of the Bureau of Mines, doing research work in economic problems of the petroleum industry, in forecasting motor-fuel demand and crude-oil requirements and determining the market demand for crude oil for the various States.

Prior to coming with the Bureau of Mines I was professor of commerce and economics at the Panhandle Agricultural and Mechanical College of Oklahoma.

I had 4½ years' practical oil experience with the United Oil Co., formerly a subsidiary of the Continental Oil Co.

I obtained my B. S. and M. S. degrees at Denver University, took graduate work at University of California and American University, and obtained my Ph. D. degree at the latter institution.

I appeared before this committee at the last hearing.

Mr. Cole. Your work for the past few weeks has been, as I understand, to bring directly up to date pages 796 to 1044 of the hearings.

Mr. Breakey. Yes.

Mr. Cole. If you want to file with the committee, Dr. Breakey, the result of your work along that line, accompanied by any preliminary statement you want to make at this time, we will be glad to have it.

Mr. Breakey. I have not brought up all of those statistics in this case, because some of them are not directly in my line and some of them I felt do not come in direct connection with this work. If there is anything else I do not offer you and you would like to have it, I will get it.

During the period since the last hearing, or from 1933 to 1938, the domestic demand for all oils has increased from 868,000,000 barrels to 1,134,000,000 barrels. Domestic motor-fuel demand has increased from 377,000,000 barrels to 522,000,000; gas oil and fuel oil from

316,000,000 barrels to 409,000,000; and kerosene from 38,000,000 barrels to 56,00,0,000.

Mr. Cole. Do you have a copy of the statement from which you are reading, Mr. Breakey?

Mr. Breakey. I beg your pardon.

Mr. Cole. Do you have a copy of the statement you are now reading from?

Mr. Breakey. Not this particular part here, but I have copies of most of the statement. This is just a sort of a summary.

Mr. Mapes. Are not your figures as to demand this year different from the figures that Mr. White gave yesterday?

Mr. Breakey. That was the 1939 domestic motor-fuel demand which will be probably around 550,000,000 barrels. I think he gave estimates for the 1939 demand. He was giving the demand for all products, I believe.

Mr. Mapes. And you are giving the demand for what?

Mr. Breakey. This demand is for all oils. In other words, these figures tie in with the figures that I gave at the last hearing.

Mr. Mapes. His estimates were materially larger than any that I have seen or heard before, and I do not understand the difference between your estimates and his.

Mr. Breakey. I would have to look that up and find it out, just what that difference is.

Mr. Mapes. If you experts do not agree, we laymen are going to get all confused.

Mr. Cole calls my attention to Mr. White's statement in the hearings. It is this:

> The total demand for all oils, as estimated for 1939—we have 9 months' statistics, and I am estimating it for the other 3, approximately—will approximate 1,415,000,000 barrels, and will represent an increase of about 380,000,000 barrels, or 37 percent, as compared with such demand in 1934.

Mr. Breakey. I could not say exactly what figure he has included in that demand for all oils.

Mr. Mapes. It is fair to say that he includes something which you do not include.

Mr. Breakey. He evidently includes exports, too, and my figure does not.

Mr. Pearson. Your figures, I understand, are just through 1938.

Mr. Breakey. That is 1938.

Mr. Pearson. The increase shown?

Mr. Breakey. Yes.

Mr. Mapes. There is not any such jump from one year to the other as the difference between your estimates and Mr. White's estimates indicate, is there?

Mr. Breakey. The increase in Mr. White's figures are from 1934 to 1939. The 1938 demand, domestic demand, is less than the 1937, although the export demand is higher.

Mr. Mapes. Is the domestic demand for this year substantially more than it was for last year?

Mr. Breakey. Yes; I think it is. It is for motor fuel, I should say. Yes; I can give you those figures here for 8 months.

The total domestic demand for the first 8 months of this year is 793.000 000 barrels, as compared with 733,000,000 in 1938.

Mr. Pearson. For the whole year 1938?

Mr. **Breakey.** No; for the 9 months of 1938.

Mr. **Pearson.** What was the 1938 figure?

Mr. **Breakey.** The 1938 figure was 733,000,000 barrels or 733,500,000, and the 1939 was 793,000,000.

Mr. **Mapes.** At the same rate for the year the total domestic deman would be, as I estimate it, 1,179,000,000 barrels, according to your figures.

Mr. **Breakey.** I have not calculated what the rate would be for the full year.

Mr. **Mapes.** So that the only way that you can account for Mr. White's estimate is that they include, in your opinion, exports as well as the domestic demands?

Mr. **Breakey.** Yes.

Mr. **Pearson.** Mr. Breakey, will you give those figures again on the increased gasoline consumption. I got the last one but not the first one.

Mr. **Breakey.** Gasoline consumption, or domestic motor-fuel demand has increased from 377,000,000 barrels in 1933 to 522,000,000 barrels in 1938.

Mr. **Pearson.** 150,000,000 barrels increase over that period of time?

Mr. **Breakey.** Yes. The economics of petroleum differ from that of most products in that over the short period of time they are not sensitive in balancing supply and demand. It is not always possible to discover new fields sufficiently fast enough to supply the demand, while, on the other hand, once the oil is discovered, it is difficult to develop production in an orderly manner because of the law of capture, which dictates that oil belongs to him who first gets it even though it may have been drained from under some other person's land.

Mr. **Mapes.** May I interrupt you there?

Mr. **Breakey.** Yes, sir.

Mr. **Mapes.** I have the impression that with the proration program which has been adopted in most of the States, and the limitation of the number of wells that may be drilled in any given area, that the law of capture does not urge people to put down competing wells now as much as was the case formerly. Is that correct?

Mr. **Breakey.** Where they have those laws and can develop them on some basis like that, why, I think that is correct; but there are still a good many parts of the country that they do not have that regulation and even where they do, there are some inconsistencies that they have been having trouble with. I think they are still having their problems in all of these States where proration is in effect.

Mr. **Mapes.** What States do not have proration laws now?

Mr. **Breakey.** Illinois, I believe, does not have any proration law.

Mr. **Mapes.** Does Louisiana?

Mr. **Breakey.** Yes.

Mr. **Mapes.** Is Illinois the chief offender?

Mr. **Breakey.** Right at the present time it is the chief offender.

Mr. **Pearson.** Does California have a proration statute?

Mr. **Breakey.** No; they do not.

Mr. **Mapes.** The industry itself takes care of it there pretty well, does it not?

Mr. **Breakey.** Yes; in California they do.

Mr. Mapes. Do you think that legislation like the bill proposed here is desirable to take care of a single State like Illinois if the other States take care of the situation pretty well themselves, or should we leave it to the State of Illinois and take care of the situation there?

Mr. Breakey. I do no feel that I am competent to answer that question. In fact, I have not studied that bill over.

I would rather let somebody else who has studied the bill over answer that. In fact, I have not even had a chance to see the bill. I just returned from a field trip and was told I was expected to testify here.

These conditions force every owner of land on an oil structure to produce oil from his land as fast as he can and result in excessive drilling, wasteful methods of production, and an oversupply of oil. Discoveries of large pools, such as Seminole, Santa Fe Springs, or the famous East Texas field have disrupted the whole economic balance of the petroleum industry.

One of the most obvious forms of waste that result from oversupply is the abandoning of stripper wells because the price is insufficient to pay the cost of production. Most of our producing wells are of this type and they supply a large proportion of the national production. If production from flush wells is permitted to cause the price to go so low that these wells must be abandoned, in which case water, wax, caving, and so forth, will almost surely prevent their future production, the Nation will have lost an irreplaceable natural resource.

Excessive production is also wasteful of our petroleum in that it causes accumulation of large stocks, which, when stored for long periods, result in loss by evaporation of the most valuable portion of the oil. In addition, there is the actual cost of storage, loss of interest, insurance, and administrative cost. The low prices that accompany overproduction and excessive stocks of petroleum make it cheaper to use crude oil for fuel without first extracting the higher quality products such as gasoline. Excessive stocks of crude oil usually exert a pressure for excessive refining, resulting in too large stocks of refined products. These are even more burdensome to carry than the crude stocks because there is a greater evaporation loss to gasoline, the investment burden is larger because of the added refinery cost, and a more expensive type of storage must be provided than for crude. This can lead to another wasteful practice—that of dumping the surplus product on a foreign market at a price below cost, because the surplus stocks if forced upon the domestic market would cause a price break that would involve a far greater loss to the owner than the dumping does.

And there what I am trying to say is not that the wastefulness is in the price break, but that if the product is marketed in foreign countries at a price less than it is in this country, merely to get rid of it, that is waste and we would not be using our resources to the greatest advantage.

Mr. Mapes. Is there an excessive—going back a few sentences in your statement—is there an excessive amount of oil in storage, in your opinion?

Mr. Breakey. Yes; I think that storages are a little bit too high at the present time; that is, refined stocks, primarily gasoline.

Mr. **Mapes.** Of crude oil?

Mr. **Breakey.** No; not of crude oil.

Mr. **Mapes.** How much too much would you say?

Mr. **Breakey.** Oh, probably I would say offhand probably about 5,000,000 barrels too high; gasoline stocks.

Mr. **Mapes.** How much is stored altogether?

Mr. **Breakey.** Well, at the end of August there was a total of 72,000,000 barrels of finished and unfinished gasoline in storage. That would be a little bit less at the end of September. I do not have the September figures.

Mr. **Mapes.** How large is the percentage in storage greater than it should be, in your opinion?

Mr. **Breakey.** I think that there should probably be about 5,000,000 barrels less than that, or about 67,000,000 barrels at the end of August.

Mr. **Mapes.** What percentage is that of the total amount?

Mr. **Breakey.** Probably about 7 percent.

Mr. **Mapes.** Would you think it desirable to pass legislation to fix the amount of storage, to take care of as small a percentage of difference as that?

Mr. **Breakey.** No; I do not think so.

Mr. **Mapes.** There is no great difference in the amount that ought to be in storage in your opinion and the amount that is actually in storage.

Mr. **Breakey.** I do not feel that there is any legislation needed to take care of that amount.

Oklahoma was one of the first States to control petroleum production. An unsuccessful attempt was made to control the production in the Cushing field, Oklahoma, by voluntary agreement, following which the Corporation Commission of Oklahoma on July 1, 1914, issued an order regulating drilling and spacing, which was the first step toward oil control. The discovery of the Seminole City pool in July 1926 again brought need for production control, which might be considered the initial development of the present proration movement.

Following this, officials of oil-producing States had conferences in an attempt to agree upon proration methods, and in 1928 President Coolidge appointed a Federal Oil Conservation Board, part of the functions of which in its later years was to forecast the market demand for crude oil.

The advent of the N. R. A. brought with it a petroleum code, effective in September 1933, which was administered by the Petroleum Administrative Board and the Secretary of the Interior as Petroleum Administrator. One function of the Petroleum Administrative Board was to forecast the market demand for petroleum and to allocate this demand to the various States.

After the termination of the code, Congress passed the Interstate Oil Compact Commission Act in September 1935, which provided for the individual States to appoint representatives to a meeting where they could confer upon problems of the oil industry. This act was supplemented by the Connally "hot oil" law, passed a few months before, which made it illegal to ship oil in interstate commerce that had been produced in violation of any State law.

In the meantime, with the demise of the Petroleum Administrative Board, the Bureau of Mines was requested by the States to carry on the work of forecasting oil demand. The States use the Bureau's forecasts as the findings of an impartial authority, and have followed them more or less closely.

The principal product of petroleum, both in quantity and value, is gasoline; therefore, the demand for gasoline, or motor fuel, is used as the prime element in estimating petroleum demand.

### THE DEMAND FOR MOTOR FUEL

Detailed statistics of the demand for refined petroleum products are not available prior to 1917. Consequently, the effect of the World War on domestic demand from 1914 to 1918 is obscure.

Mr. **Cole**. Mr. Breakey, may I interrupt you? You said that the States followed the figures as to the demand declared by the Federal agencies.

Mr. **Breakey**. More or less closely.

Mr. **Cole**. Yes.

Mr. **Breakey**. Yes.

Mr. **Cole**. Does that apply to Illinois?

Mr. **Breakey**. No; it does not.

Mr. **Cole**. Do you allocate a definite quantity to Illinois?

Mr. **Breakey**. We estimate the demand for Illinois; yes.

Mr. **Cole**. Have you any figures before you as estimates for Illinois over the last 3 or 4 months and a parallel column of what the production of that State has been?

Mr. **Breakey**. No; I do not have those figures with me.

Mr. **Cole**. Are the figures available?

Mr. **Breakey**. They are available; yes. I can supply them.

Mr. **Cole**. I wish you would.

Mr. **Breakey**. I will do that.

Mr. **Cole**. How about California?

Mr. **Breakey**. California has been a little bit higher than the recommendations, but not nearly as out of line as Illinois.

Would you like to have California figures supplied also?

Mr. **Cole**. Yes.

(The figures requested are as follows:)

*Demand and actual production of crude oil in Illinois and California, first 9 months of 1939, submitted by H. A. Breakey at the request of Congressman Cole*

[Daily average barrels]

| | Illinois | | California | |
|---|---|---|---|---|
| | Estimated demand | Actual production | Estimated demand | Actual production |
| January | 86, 100 | 143, 400 | 588, 400 | 621, 700 |
| February | 102, 500 | 162, 200 | 580, 000 | 622, 100 |
| March | 125, 500 | 173, 500 | 588, 400 | 622, 100 |
| April | 149, 300 | 180, 500 | 592, 000 | 613, 500 |
| May | 159, 700 | 220, 900 | 582, 600 | 615, 300 |
| June | 174, 300 | 236, 100 | 594, 600 | 607, 400 |
| July | 187, 400 | 281, 800 | 595, 200 | 606, 600 |
| August | 201, 900 | 317, 800 | 595, 100 | 610, 800 |
| September | 248, 700 | 348, 100 | 596, 000 | 615, 400 |

The production in Illinois during the first 9 months of 1939 has ranged from 21 to 67 percent above the Bureau of Mines estimates, averaging about 40 percent. If all of the States had exceeded the estimates to this extent, there would be almost 1,500,000 barrels per day of excess production.

*State allowables and Bureau of Mines estimates of required production*[1] *compared with actual production, 1935–36*

[Daily averages, in thousands of barrels of 42 gallons]

| | Jan. | Feb. | Mar. | Apr. | May | June | July[2] | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1935 | | | | | | | | | | | | | |
| Texas: | | | | | | | | | | | | | |
| State allowable[3] | 1,029 | 1,048 | 1,053 | 1,046 | 1,064 | 1,083 | 1,065 | 1,038 | 1,045 | 1,044 | 1,085 | 1,093 | 1,058 |
| Bureau of Mines estimate | 1,007 | 1,032 | 1,020 | 1,021 | 1,033 | 1,059 | 1,064 | 1,062 | 1,060 | 1,026 | 1,028 | 1,006 | 1,035 |
| Actual production | 1,031 | 1,077 | 1,082 | 1,056 | 1,067 | 1,090 | 1,074 | 1,060 | 1,069 | 1,064 | 1,094 | 1,094 | 1,076 |
| Oklahoma: | | | | | | | | | | | | | |
| State allowable[4] | 489 | 497 | 491 | 493 | 500 | 514 | 517 | 491 | 491 | 493 | 492 | 480 | 496 |
| Bureau of Mines estimate | 489 | 497 | 491 | 493 | 500 | 514 | 517 | 516 | 506 | 493 | 492 | 480 | 499 |
| Actual production | 491 | 490 | 505 | 522 | 523 | 518 | 530 | 495 | 498 | 515 | 511 | 496 | 508 |
| California: | | | | | | | | | | | | | |
| State allowable[5] | 474 | 489 | 493 | 493 | 494 | 526 | 510 | 543 | 530 | 591 | 591 | 591 | 527 |
| Bureau of Mines estimate | 474 | 489 | 493 | 493 | 494 | 513 | 513 | 512 | 500 | 498 | 505 | 514 | 500 |
| Actual production | 500 | 499 | 498 | 473 | 495 | 557 | 562 | 600 | 640 | 650 | 677 | 678 | 569 |
| Kansas: | | | | | | | | | | | | | |
| State allowable[6] | 142 | 154 | 143 | 141 | 148 | 154 | 156 | 140 | 141 | 146 | 143 | 139 | 146 |
| Bureau of Mines estimate | 137 | 139 | 140 | 141 | 148 | 154 | 156 | 155 | 152 | 146 | 143 | 139 | 146 |
| Actual production | 137 | 149 | 156 | 152 | 153 | 154 | 157 | 149 | 152 | 154 | 146 | 144 | 150 |
| Louisiana: | | | | | | | | | | | | | |
| State allowable[7] | 108 | 114 | 115 | 116 | 120 | 132 | 140 | 139 | 143 | 143 | 149 | 157 | 150 |
| Bureau of Mines estimate | 100 | 110 | 111 | 111 | 112 | 132 | 130 | 130 | 126 | 125 | 127 | 128 | 120 |
| Actual production | 111 | 114 | 116 | 127 | 134 | 137 | 139 | 141 | 146 | 153 | 157 | 163 | 138 |
| New Mexico: | | | | | | | | | | | | | |
| State allowable[8] | 52 | 50 | 53 | 53 | 55 | 57 | 59 | 60 | 60 | 60 | 61 | 62 | 57 |
| Bureau of Mines estimate | 50 | 49 | 49 | 50 | 52 | 55 | 54 | 54 | 51 | 51 | 52 | 56 | 52 |
| Actual production | 54 | 50 | 54 | 55 | 54 | 56 | 58 | 59 | 59 | 59 | 60 | 60 | 56 |
| Illinois: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 12 | 12 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| Actual production | 11 | 11 | 12 | 11 | 12 | 12 | 12 | 12 | 12 | 13 | 12 | 11 | 12 |
| Other States: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 191 | 198 | 205 | 207 | 211 | 213 | 215 | 215 | 207 | 204 | 206 | 206 | 206 |
| Actual production | 204 | 209 | 206 | 218 | 222 | 221 | 226 | 220 | 228 | 236 | 226 | 216 | 221 |
| United States: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 2,460 | 2,526 | 2,520 | 2,527 | 2,561 | 2,651 | 2,660 | 2,655 | 2,613 | 2,554 | 2,564 | 2,540 | 2,569 |
| Actual production | 2,539 | 2,599 | 2,629 | 2,614 | 2,660 | 2,745 | 2,758 | 2,736 | 2,804 | 2,844 | 2,883 | 2,862 | 2,730 |

[1] The estimates of the Bureau of Mines start with July 1935, the data for the first 6 months of 1935 being the allocations of the Federal Agency under the Petroleum Code.
[2] Bureau of Mines started making estimates of market demand in July 1935. Prior to this time they were made by the Federal agency under the code.
[3] Railroad Commission of Texas.
[4] Corporation Commission of Oklahoma.
[5] Central Committee of California Oil Producers.
[6] Corporation Commission of Kansas.
[7] Department of Conservation, Louisiana.
[8] Oil Conservation Commission of New Mexico.

*State allowables and Bureau of Mines estimates of required production*[1] *compared with actual production, 1935–36*—Continued.

| | Jan. | Feb. | Mar. | Apr. | May | June | July[2] | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1936 | | | | | | | | | | | | | |
| Texas: | | | | | | | | | | | | | |
| State allowable[3] | 1. 060 | 1, 106 | 1, 147 | 1, 191 | 1, 188 | 1, 172 | 1, 172 | 1, 193 | 1, 171 | 1, 219[9] | 1, 170 | 1, 246 | 1, 170 |
| Bureau of Mines estimate | 1. 017 | 1, 068 | 1, 104 | 1, 123 | 1, 133 | 1, 126 | 1, 147 | 1, 155 | 1, 124 | 1, 107 | 1, 109 | 1, 145 | 1, 113 |
| Actual production | 1, 066 | 1, 124 | 1, 144 | 1, 188 | 1, 188 | 1, 179 | 1, 159 | 1, 205 | 1, 160 | 1, 206 | 1, 160 | 1, 229 | 1, 168 |
| Oklahoma: | | | | | | | | | | | | | |
| State allowable[4] | 481 | 484 | 506 | 525 | 538 | 525 | 526 | 576 | 563 | 560 | 558 | 595 | 536 |
| Bureau of Mines estimate | 481 | 484 | 506 | 525 | 538 | 553 | 570 | 576 | 563 | 560 | 558 | 567 | 540 |
| Actual production | 513 | 516 | 548 | 574 | 576 | 563 | 547 | 586 | 581 | 589 | 581 | 605 | 564 |
| California: | | | | | | | | | | | | | |
| State allowable[5] | 640 | 537 | 539 | 539 | 540 | 544 | 544 | 544 | 544 | 544 | 544 | 551 | 551 |
| Bureau of Mines estimate | 518 | 530 | 539 | 553 | 544 | 536 | 551 | 550 | 535 | 535 | 550 | 553 | 541 |
| Actual production | 680 | 587 | 566 | 573 | 577 | 582 | 575 | 578 | 579 | 579 | 582 | 584 | 587 |
| Kansas: | | | | | | | | | | | | | |
| State allowable[6] | 134 | 137 | 142 | 150 | 150 | 145 | 152 | 167 | 160 | 155 | 155 | 163 | 150 |
| Bureau of Mines estimate | 134 | 137 | 142 | 146 | 150 | 153 | 164 | 167 | 160 | 155 | 155 | 156 | 151 |
| Actual production | 144 | 139 | 155 | 164 | 156 | 152 | 160 | 169 | 167 | 166 | 166 | 174 | 159 |
| Louisiana: | | | | | | | | | | | | | |
| State allowable[7] | 169 | 181 | 187 | 202 | 213 | 217 | 225 | 230 | 235 | 235 | 238 | 238 | 214 |
| Bureau of Mines estimate | 133 | 141 | 151 | 161 | 171 | 176 | 187 | 189 | 186 | 189 | 199 | 205 | 174 |
| Actual production | 180 | 190 | 205 | 216 | 225 | 221 | 224 | 227 | 232 | 233 | 229 | 236 | 220 |
| New Mexico: | | | | | | | | | | | | | |
| State allowable[8] | 62 | 64 | 69 | 71 | 75 | 73 | 74 | 78 | 80 | 82 | 84 | 86 | 75 |
| Bureau of Mines estimate | 59 | 61 | 64 | 63 | 66 | 68 | 69 | 70 | 72 | 74 | 76 | 78 | 68 |
| Actual production | 62 | 65 | 69 | 70 | 75 | 73 | 74 | 75 | 76 | 82 | 83 | 87 | 74 |
| Illinois: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 11 | 11 | 12 | 11 | 12 | 12 | 12 | 13 | 12 | 12 | 12 | 12 | 12 |
| Actual production | 11 | 10 | 13 | 12 | 13 | 13 | 13 | 12 | 13 | 13 | 12 | 13 | 12 |
| Other States: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 206 | 216 | 221 | 215 | 212 | 214 | 217 | 217 | 212 | 210 | 211 | 214 | 215 |
| Actual production | 209 | 201 | 222 | 219 | 214 | 223 | 218 | 215 | 224 | 222 | 221 | 222 | 221 |
| United States: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 2, 559 | 2, 648 | 2, 739 | 2, 797 | 2, 826 | 2, 838 | 2, 917 | 2, 937 | 2, 864 | 2, 842 | 2, 870 | 2, 930 | 2, 814 |
| Actual production | 2, 865 | 2, 832 | 2, 922 | 3, 016 | 3, 024 | 3, 006 | 2, 970 | 3, 067 | 3, 032 | 3, 090 | 3, 034 | 3, 150 | 3, 005 |

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[1] The estimates of the Bureau of Mines start with July 1935, the data for the first 6 months of 1935 being the allocations of the Federal Agency under the Petroleum Code.

[2] Bureau of Mines started making estimates of market demand in July 1935. Prior to this time they were made by the Federal agency under the code.

[3] Railroad Commission of Texas.

[4] Corporation Commission of Oklahoma.

[5] Central Committee of California Oil Producers.

[6] Corporation Commission of Kansas.

[7] Department of Conservation, Louisiana.

[8] Oil Conservation Commission of New Mexico.

[9] Prior to November 1936 estimates of crude-stock changes were included in market-demand estimates, hence since that date the figures have been estimates of demand rather than of required production.

### *State allowables and Bureau of Mines estimates of market demand,*[1] *compared with actual production in the United States, in 1937*

[Daily averages, in thousands of barrels]

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Texas: | | | | | | | | | | | | | |
| State allowable [2] | 1, 296 | 1, 371 | 1, 443 | 1, 408 | 1, 465 | 1, 419 | 1, 444 | 1, 566 | 1, 517 | 1, 480 | 1, 375 | 1, 360 | 1, 314 |
| Bureau of Mines estimate | 1, 176 | 1, 203 | 1, 257 | 1, 298 | 1, 341 | 1, 354 | 1, 375 | 1, 395 | 1, 414 | 1, 430 | 1, 413 | 1, 400 | 1, 338 |
| Actual production | 1, 268 | 1, 349 | 1, 405 | 1, 383 | 1, 431 | 1, 391 | 1, 416 | 1, 525 | 1, 483 | 1, 446 | 1, 354 | 1, 337 | 1, 398 |
| Oklahoma: | | | | | | | | | | | | | |
| State allowable [3] | 573 | 582 | 621 | 621 | 623 | 625 | 630 | 633 | 600 | 600 | 575 | 550 | 603 |
| Bureau of Mines estimate | 573 | 582 | 591 | 610 | 623 | 625 | 630 | 633 | 634 | 629 | 598 | 589 | 610 |
| Actual production | 605 | 622 | 651 | 681 | 665 | 639 | 648 | 651 | 617 | 599 | 580 | 569 | 627 |
| California: | | | | | | | | | | | | | |
| State allowable [4] | 551 | 551 | 551 | 580 | 602 | 603 | 603 | 613 | 638 | 660 | 675 | 675 | 609 |
| Bureau of Mines estimate | 560 | 573 | 571 | 580 | 583 | 586 | 606 | 613 | 638 | 660 | 675 | 679 | 610 |
| Actual production | 582 | 590 | 594 | 627 | 657 | 664 | 664 | 673 | 685 | 695 | 702 | 705 | 653 |
| Kansas: | | | | | | | | | | | | | |
| State allowable [5] | 176 | 188 | 187 | 190 | 187 | 196 | 200 | 199 | 197 | 192 | 181 | 176 | 189 |
| Bureau of Mines estimate | 166 | 170 | 178 | 183 | 187 | 191 | 196 | 201 | 201 | 200 | 190 | 186 | 187 |
| Actual production | 171 | 189 | 195 | 201 | 206 | 201 | 207 | 201 | 197 | 194 | 186 | 178 | 194 |
| Louisiana: | | | | | | | | | | | | | |
| State allowable [6] | 241 | 236 | 236 | 236 | 241 | 255 | 264 | 265 | 266 | 267 | 253 | 254 | 251 |
| Bureau of Mines estimate | 216 | 225 | 240 | 245 | 249 | 252 | 253 | 254 | 248 | 255 | 246 | 244 | 244 |
| Actual production | 240 | 238 | 242 | 240 | 246 | 257 | 258 | 264 | 264 | 245 | 239 | 242 | 249 |
| New Mexico: | | | | | | | | | | | | | |
| State allowable [7] | 93 | 98 | 103 | 106 | 114 | 115 | 115 | 114 | 114 | 104 | 105 | 108 | 107 |
| Bureau of Mines estimate | 80 | 82 | 88 | 91 | 100 | 102 | 101 | 101 | 101 | 106 | 105 | 104 | 97 |
| Actual production | 90 | 99 | 102 | 105 | 112 | 111 | 110 | 111 | 114 | 106 | 107 | 109 | 106 |
| Illinois: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 15 | 17 | 21 | 24 | 15 |
| Actual production | 12 | 12 | 13 | 13 | 13 | 15 | 17 | 22 | 28 | 29 | 33 | 35 | 20 |
| Other States: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 214 | 221 | 221 | 223 | 237 | 243 | 250 | 253 | 258 | 271 | 261 | 265 | 243 |
| Actual production | 212 | 229 | 241 | 249 | 248 | 249 | 252 | 266 | 278 | 264 | 273 | 263 | 258 |
| United States: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 2, 998 | 3, 069 | 3, 159 | 3, 243 | 3, 333 | 3, 366 | 3, 424 | 3, 463 | 3, 509 | 3, 568 | 3, 509 | 3, 491 | 3, 344 |
| Actual production | 3, 180 | 3, 328 | 3, 443 | 3, 499 | 3, 578 | 3, 527 | 3, 572 | 3, 713 | 3, 666 | 3, 578 | 3, 474 | 3, 438 | 3, 505 |

[1] Beginning November 1936, the State figures have been estimates of demand rather than required production as formerly; hence, in comparing the demand data with actual production due regard should be given to changes in stocks by States of origin.

[2] Railroad Commission of Texas.

[3] Corporation Commission of Oklahoma. State allowable figures as shown do not include production permitted in accordance with "underage" and other special provisions of State orders.

[4] Central Committee of California Oil Producers.

[5] Corporation Commission of Kansas. January–May State allowable figures are those announced in general State orders; June–December figures are totals of allowables calculated separately for each field. State allowable figures shown do not include production permitted in accordance with "underage" provisions of said orders.

[6] Department of Conservation, Louisiana. State allowable figures shown do not include production permitted under special orders of said department.

[7] Oil Conservation Commission of New Mexico.

*State allowables and Bureau of Mines estimates of market demand,[1] compared with actual production in the United States, in 1938*

[Daily averages, in thousands of barrels]

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Texas: | | | | | | | | | | | | | |
| State allowable [2] | 1, 331 | 1, 273 | 1, 342 | 1, 366 | 1, 220 | 1, 206 | 1, 386 | 1, 443 | 1, 260 | 1, 309 | 1, 311 | 1, 325 | 1, 314 |
| Bureau of Mines estimate | 1, 351 | 1, 366 | 1, 345 | 1, 330 | 1, 323 | 1, 329 | 1, 360 | 1, 378 | 1, 399 | 1, 359 | 1, 371 | 1, 344 | 1, 355 |
| Actual production | 1, 318 | 1, 273 | 1, 339 | 1, 351 | 1, 216 | 1, 212 | 1, 365 | 1, 412 | 1, 261 | 1, 282 | 1, 295 | 1, 307 | 1, 304 |
| Oklahoma: | | | | | | | | | | | | | |
| State allowable [3] | 550 | 500 | 475 | 475 | 423 | 405 | 428 | 428 | 428 | 428 | 428 | 428 | 450 |
| Bureau of Mines estimate | 567 | 570 | 548 | 527 | 510 | 508 | 518 | 530 | 528 | 524 | 515 | 501 | 529 |
| Actual production | 562 | 535 | 526 | 505 | 464 | 431 | 450 | 471 | 469 | 454 | 441 | 446 | 479 |
| California: | | | | | | | | | | | | | |
| State allowable [4] | 678 | 694 | 695 | 699 | 620 | 620 | 620 | 615 | 615 | 615 | 615 | 615 | 642 |
| Bureau of Mines estimate | 678 | 694 | 695 | 699 | 668 | 650 | 642 | 649 | 638 | 619 | 617 | 590 | 653 |
| Actual production | 710 | 736 | 724 | 722 | 689 | 672 | 661 | 670 | 664 | 659 | 663 | 646 | 684 |
| Kansas: | | | | | | | | | | | | | |
| State allowable [5] | 186 | 182 | 183 | 184 | 160 | 168 | 171 | 168 | 163 | 161 | 162 | 162 | 171 |
| Bureau of Mines estimate | 179 | 176 | 177 | 173 | 169 | 172 | 172 | 169 | 168 | 163 | 164 | 159 | 170 |
| Actual production | 183 | 171 | 171 | 170 | 153 | 157 | 157 | 167 | 161 | 156 | 157 | 156 | 165 |
| Louisiana: | | | | | | | | | | | | | |
| State allowable [6] | 256 | 245 | 247 | 252 | 251 | 250 | 250 | 257 | 260 | 260 | 236 | 248 | 251 |
| Bureau of Mines estimate | 238 | 239 | 239 | 240 | 243 | 250 | 261 | 256 | 255 | 248 | 256 | 248 | 248 |
| Actual production | 253 | 258 | 259 | 257 | 257 | 261 | 264 | 260 | 265 | 272 | 256 | 255 | 261 |
| New Mexico: | | | | | | | | | | | | | |
| State allowable [7] | 105 | 101 | 101 | 106 | 97 | 91 | 102 | 107 | 106 | 105 | 106 | 98 | 102 |
| Bureau of Mines estimate | 103 | 105 | 105 | 106 | 104 | 108 | 113 | 112 | 112 | 109 | 111 | 100 | 107 |
| Actual production | 105 | 104 | 102 | 98 | 93 | 87 | 94 | 96 | 96 | 100 | 103 | 98 | 98 |
| Arkansas: | | | | | | | | | | | | | |
| State allowable [8] | 40 | 47 | 50 | 55 | 41 | 45 | 53 | 55 | 56 | 51 | 48 | 50 | 49 |
| Bureau of Mines estimate | 35 | 37 | 38 | 40 | 45 | 48 | 51 | 54 | 54 | 54 | 52 | 52 | 47 |
| Actual production | 42 | 48 | 50 | 53 | 41 | 42 | 54 | 55 | 57 | 52 | 49 | 50 | 50 |
| Illinois: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 27 | 30 | 31 | 35 | 40 | 42 | 46 | 49 | 49 | 52 | 64 | 72 | 45 |
| Actual production | 36 | 40 | 43 | 46 | 46 | 45 | 53 | 67 | 85 | 89 | 102 | 128 | 67 |
| Other States: | | | | | | | | | | | | | |
| Bureay of Mines estimate | 229 | 221 | 214 | 212 | 216 | 226 | 235 | 241 | 241 | 239 | 241 | 240 | 229 |
| Actual production | 211 | 216 | 222 | 221 | 224 | 236 | 221 | 227 | 231 | 221 | 220 | 214 | 219 |
| United States: | | | | | | | | | | | | | |
| Bureau of Mines estimate | 3, 407 | 3, 438 | 3, 392 | 3, 362 | 3, 318 | 3, 333 | 3, 398 | 3, 438 | 3, 444 | 3, 367 | 3, 391 | 3, 306 | 3, 383 |
| Actual production | 3, 420 | 3. 381 | 3, 436 | 3, 423 | 3, 183 | 3, 143 | 3, 319 | 3, 425 | 3, 289 | 3, 285 | 3, 286 | 3, 300 | 3, 327 |

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[1] Beginning November 1936, the State figures have been estimates of demand rather than required production as formerly; hence, in comparing the demand data with actual production due regard should be given to changes in stocks by States of origin. (Chages in stocks and demand are given elsewhere in this chapter.)

[2] Railroad Commission of Texas.

[3] Corporation Commission of Oklahoma. State allowable figures as shown do not include production permitted in accordance with "underage" and other special provisions of State orders.

[4] Central Committee of California Oil Producers.

[5] State Corporation Commission of Kansas.

[6] Department of Conservation, Louisiana. State allowable figures shown do not include production permitted under special orders of said department.

[7] Oil Conservation Commission of New Mexico. State allowable figures as shown do not include production permitted in accordance with "underage" and other special provisions of State orders.

[8] Oil and Gas Commission.

*Bureau of Mines estimates of market demand, compared with actual production, 1939*

[Daily averages in thousands of barrels]

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct.[1] | Nov. | Average Jan.-Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Texas: | | | | | | | | | | | | |
| Estimate | 1,333 | 1,298 | 1,364 | 1,413 | 1,406 | 1,427 | 1,427 | 1,428 | 1,408 | 1,445 | 1,444 | 1,395 |
| Production | 1,314 | 1,298 | 1,353 | 1,424 | 1,403 | 1,313 | 1,377 | 810 | 1,401 | 1,400 | ------ | 1,309 |
| California: | | | | | | | | | | | | |
| Estimate | 588 | 580 | 588 | 592 | 583 | 595 | 595 | 595 | 596 | 595 | 596 | 591 |
| Production | 622 | 622 | 622 | 614 | 615 | 607 | 607 | 611 | 615 | 620 | ------ | 616 |
| Oklahoma: | | | | | | | | | | | | |
| Estimate | 500 | 483 | 473 | 473 | 456 | 450 | 456 | 448 | 429 | 424 | 429 | 459 |
| Production | 450 | 474 | 477 | 469 | 478 | 475 | 450 | 237 | 420 | 425 | ------ | 436 |
| Illinois: | | | | | | | | | | | | |
| Estimate | 86 | 103 | 126 | 149 | 160 | 174 | 187 | 202 | 249 | 276 | 303 | 171 |
| Production | 143 | 162 | 174 | 181 | 221 | 236 | 282 | 318 | 348 | 340 | ------ | 241 |
| Louisiana: | | | | | | | | | | | | |
| Estimate | 242 | 247 | 260 | 262 | 262 | 265 | 265 | 259 | 256 | 260 | 259 | 258 |
| Production | 259 | 266 | 259 | 270 | 267 | 268 | 270 | 177 | 243 | 265 | ------ | 254 |
| Kansas: | | | | | | | | | | | | |
| Estimate | 154 | 149 | 150 | 153 | 153 | 152 | 160 | 169 | 166 | 171 | 169 | 158 |
| Production | 159 | 152 | 177 | 174 | 173 | 174 | 177 | 102 | 169 | 170 | ------ | 163 |
| New Mexico: | | | | | | | | | | | | |
| Estimate | 96 | 100 | 110 | 115 | 116 | 117 | 116 | 111 | 109 | 114 | 111 | 110 |
| Production | 99 | 98 | 106 | 105 | 107 | 107 | 109 | 56 | 101 | 115 | ------ | 100 |
| United States: | | | | | | | | | | | | |
| Estimate | 3,271 | 3,220 | 3,340 | 3,434 | 3,425 | 3,491 | 3,513 | 3,522 | 3,511 | 3,590 | 3,620 | 3,432 |
| Production | 3,306 | 3,338 | 3,444 | 3,517 | 3,566 | 3,487 | 3,579 | 2,609 | 3,606 | 3,650 | ------ | 3,410 |

[1] Production figures estimated on basis of American Petroleum Institute data.

Mr. BREAKEY. Detailed statistics of the demand for refined petroleum products are not available prior to 1917. Consequently, the effect of the World War on domestic demand from 1914–18 is obscure.

This was a period of rapid growth in motorization, as indicated by the increase in total motor vehicles registered in the United States from 1,711,339 on December 31, 1914, to 6,146,617 vehicles on December 31, 1918.

Mr. COLE. What year was that?

Mr. BREAKEY. 1918.

Mr. COLE. 1918.

Mr. BREAKEY. Yes. In other words, I am trying to give the period during the World War years.

Mr. COLE. Oh, yes. Well, how many do we have now, as of December 31?

Mr. BREAKEY. It would be a little bit less than 30,000,000. I can give you the exact figures. These figures are not registration figures. They are motor vehicles in use on July 1. July 1, 1938, there were 28,000,000 in use; registration would be somewhat more than that.

During this period the number of motor trucks increased from 85,600 to 525,000. A large part of the increase was due to the natural expansion in the new means of transport.

The yield of gasoline from crude oil refined rose from less than 11 percent in 1909 to about 15 percent in 1914, and to over 25 percent in 1918. This compares with the current yield of over 44 percent, which could be increased materially if necessary. Today, increased demand for gasoline could be met with much less relative increase in the amount of crude required, provided the demand for other products did not increase in proportion.

The domestic demand for motor fuel probably approximated 23,000,000 barrels in 1914, compared with about 76,000,000 barrels in

1918. In 1939, domestic demand will establish a new record and will probably exceed 550,000,000 barrels.

Exports of motor fuel rose from about 5,000,000 barrels in 1914 to about 14,000,000 in 1918. The peak year for exports was in 1930, with a total close to 66,000,000 barrels. Thereafter they fell to 25,000,000 in 1934 and then rose to 50,000,000 barrels in 1938.

*Distribution of United States domestic automotive motor-fuel demand*

[Thousands of barrels of 42 gallons]

| | Domestic total motor-fuel demand | Automotive demand | Passenger cars | | | Trucks | | | Total busses |
|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Highway | City | Total | Highway | City | |
| 1925 | 226, 329 | 201, 433 | 154, 938 | 80, 653 | 74, 285 | 43, 104 | 8, 466 | 34, 638 | 3, 391 |
| 1926 | 264, 391 | 235, 308 | 181, 239 | 93, 666 | 87, 573 | 49, 420 | 10, 131 | 39, 289 | 4. 649 |
| 1927 | 299, 818 | 266, 839 | 205, 983 | 105, 553 | 100, 430 | 55, 397 | 12, 068 | 43, 329 | 5, 458 |
| 1928 | 332, 033 | 295, 509 | 227, 497 | 115, 422 | 112, 075 | 60, 764 | 14, 295 | 46, 469 | 7, 248 |
| 1929 | 375, 999 | 334, 649 | 256, 899 | 128. 943 | 127, 956 | 68, 346 | 17, 417 | 50, 929 | 9, 394 |
| 1930 | 394, 800 | 351, 372 | 270, 347 | 133, 454 | 136, 893 | 70, 140 | 19, 765 | 50, 375 | 10, 885 |
| 1931 | 403, 418 | 359, 042 | 276, 828 | 134, 276 | 142, 552 | 70, 746 | 22, 132 | 48, 614 | 11, 468 |
| 1932 | 373, 900 | 332, 771 | 256, 968 | 122, 355 | 134, 613 | 64, 353 | 22, 239 | 42, 114 | 11, 450 |
| 1933 | 377, 003 | 335, 533 | 257, 301 | 121, 966 | 135, 335 | 66, 782 | 23, 871 | 42, 911 | 11, 450 |
| 1934 | [1] 410, 339 | 365, 200 | 277, 748 | 131, 183 | 146, 565 | 74, 952 | 27, 532 | 47, 420 | 12. 500 |
| 1935 | 434, 810 | 386, 981 | 291, 756 | 137, 316 | 154, 440 | 81, 725 | 30, 750 | 50, 975 | 13, 500 |
| 1936 | 481, 606 | 428, 629 | 321, 024 | 150, 896 | 170, 128 | 93, 105 | 35, 462 | 57, 643 | 14, 500 |
| 1937 | 519, 352 | 462, 223 | 343, 916 | 161, 302 | 182, 614 | 102, 807 | 39, 723 | 63. 084 | 15, 500 |
| 1938 | 521, 657 | 464, 275 | 347, 353 | 161, 390 | 185, 963 | 101, 662 | 40, 649 | 60. 973 | 15, 300 |

[1] Demand includes natural gasoline losses from 1934 on. Other figures of the Bureau which do not include these losses in 1934 indicate the domestic demand as 407,106,000 barrels in that year.

Mr. Pearson. Is there any particular reason, Mr. Breakey, that you recall for that increase in 1930?

Mr. Breakey. In which year?

Mr. Pearson. In 1930. You said that it rose to 66,000,000 barrels.

Mr. Breakey. Oh, no; I think possibly Mr. Redfield who follows me can explain that. He keeps in closer contact with the export situation.

The ratio of motor-fuel production to crude oil runs—yield—of 44 percent—47 percent including natural gasoline—gives some indication of the importance of motor fuel as a product of petroleum. Since the price of gasoline though is considerably higher than that of the products next in importance quantitatively, its importance from a value standpoint is greatly increased.

The domestic demand for gas oil and distillate fuel oils was 36 percent higher in 1938 than in 1935, compared with an increase of only 20 percent in motor fuel demand for this period. This is reflected in an increase in yield of gas oil and distillate fuel oils from 10.4 percent in 1935 to 13 percent in 1938. This increase has been at the expense of residual fuel oil, lubricants, and shortage, the yields of which declined during the years 1935–38 from 26.9 to 25.3 percent, from 2.9 to 2.6 percent, and from 1.2 to 0.6 percent, respectively. The summary of percentage yields in the appendix shows the yields of various refined products from 1932–38.

The percentage yield of gasoline from crude oil reached a peak of 44.7 in 1932. From that time it declined slightly in the succeeding years, but in 1938 it rose to 44.3 from 43.9 in 1937. This failure of the gasoline yield to increase during recent years in the light of improved refining technology probably is due chiefly to the demand for increasingly better gasoline, both for automobiles and for airplanes, and slightly to the increased demand for heating oil.

The demand for better gasoline has put pressure on refiners to produce motor fuel with ever higher octane rating. Octane qualifications first appeared on October 19, 1931, when a 57–65 octane rating was required for regular-grade gasoline. This was changed on May 8, 1933, to 60–64 octane; on August 6, 1934, to 63–70 octane; on April 15, 1935, to 68–70 octane; and on April 20, 1937, to 67–69 octane. Army airplanes and many air-transport planes now require 100-octane fuel.

The two principal methods open to refiners in the earlier days for increasing the octane rating of their motor fuel were to add tetraethyl lead and to reform. The loss by reforming or cracking gasoline has been one of the most expensive losses, probably around 20 to 25 percent, and is probably the principal cause for the decline in the gasoline yield in recent years.

During the very recent period, polymerization, alkylation, and catalytic cracking have made their advent in the manufacture of high-octane fuels. The principal source of charging stock for the first two methods at the present time is the gas constituting the loss in reforming just referred to from the cracking stills. This probably has had some influence upon the reversal in trend of gasoline yields in 1938 and 1939.

It is possible that a small amount of the increased distillates yield was contributed at the expense of motor fuel but is concealed by a gasoline yield which has been increased because of the recovery of these still gases by the new refining methods. The decline from 1.2 to 0.6 percent in the shortage item is more likely to indicate this than that the former shortage is now contributing to the increased distillate fuel oil production.

Some of the ways that the distillate fuel oil yield may be increased at the expense of the gasoline yield are by selecting a crude oil that contains less gasoline and higher proportions of distillate fuel oil, by cracking less distillate fuel oil, and by selling distillate fuel oil rather than using it for recycling in the cracking operations. Whether the distillate fuel oil will be cracked or not probably is determined largely by the economics of the individual refiner. If the difference in the price he can get for the high-octane gasoline produced by the cracking and the price he can get for distillate fuel oil is more than the cost of cracking, there will be a strong urge for him to crack the oil. However, if the refiner already has the cracking plant, he might prefer to crack the oil without an adequate profit rather than let the plant lie idle.

The average price at refineries in Oklahoma in 1938 for No. 1 straw distillate was 3.88 cents per gallon compared with 5.23 cents per gallon for premium-grade motor fuel.

Experience in the World War of 1914–18 offers little parallel for the possible demands in modern military operations. It should be borne in mind, however, that total normal consumption is now so large, the refinery operations are so much more flexible, and that so many other important sources of supply are available, that any increased world demands could be met with comparatively little effort. Thus far, severe rationing policies in both neutral and belligerent countries have been put in effect to conserve existing stocks until problems of transport and of available supplies can be determined.

Many factors enter into the demand for motor fuel, a study of which is necessary in order to forecast that demand. The domestic demand for motor fuel has swept upward so fast that it has exceeded the highest expectations of those who attempted to predict it.

About 89 percent of the domestic motor-fuel demand is used by motor vehicles, and the use of nonautomotive motor fuel is sufficiently similar, so that it need not be considered separately. Hence the two principal factors which determine the amount of motor fuel that is used are the number of automobiles in use and the quantity of gasoline consumed by each.

The number of automobiles in use is the most important factor and it is the hardest one to forecast, principally because of erratic conditions arising during and since the depression. Cars are being made of sturdier construction, resulting in longer life despite their greater annual mileage. This change could probably be taken care of on a trend basis, except that during the depression many persons put their cars in storage, which should add to the number of years of life of those cars. In many States cars were permitted to operate without proper tags. These two circumstances made registration statistics and scrappage calculations for a number of years unreliable.

Mr. Cole. You stated a moment ago that any reasonable increase in world demand could be met without any difficulty.

Mr. Breakey. May I ask for that question again?

Mr. Cole. What was the statement you made just a moment ago about the ability of the industry to meet any reasonable increase at the present time of world demands?

Mr. Breakey. I said it should be borne in mind, however, that total normal consumption is now so large, that refinery operations are so much more flexible, and that so many other important sources of supply are available, that any increased world demands could be met with comparatively little effort.

Mr. Cole. That is what I had reference to. That is taking into consideration the world as it is today?

Mr. Breakey. Yes, sir.

Mr. Cole. Do you cover the gasoline taxes and the prices of gasoline in your work?

Mr. Breakey. No; I have not included that.

Mr. Cole. All right.

Mr. Breakey. The number of motor vehicles in use at the beginning of the year is calculated by subtracting the new-car registrations for the year from the total registrations as compiled by the Bureau of Public Roads. The number of motor vehicles scrapped is obtained by subtracting those in use at the end of the year—beginning of subsequent year—from the total registrations for the year. Calculations of motor vehicles scrapped are 2 years behind by this method, making it necessary to estimate the number scrapped for the current year and for the previous year, or last year that registration statistics are available.

The number of motor vehicles in use the first day of each month are calculated by adding to the number in use on January 1, of any year the new-car registrations and subtracting the estimated cars scrapped each month. This latter figure is obtained by apportioning the number of cars scrapped for the year on a monthly basis.

### MOTOR FUEL DEMAND PER MOTOR VEHICLE

The second dominant factor in motor-fuel demand is the demand per motor vehicle. This is dependent upon several subfactors, the most important of which are long-time trend, seasonal variation, economic conditions, weather, speculation, and inconsistencies in export statistics.

The trend is made up of factors that are comparatively constant, in contrast with those which fluctuate from month to month or even from year to year. The two principal factors are the average distance traveled per unit of time by the average automobile and the average miles traveled per gallon or gasoline used. Some of the factors that enter into the average distance traveled are speed, or the mileage that can be covered in a given time; the convenience for using the automobile, which involves traffic problems, parking conveniences and costs, ease of using other transportation, and facilities for overcoming unfavorable weather. The commercial use of automobiles is another important factor in the average distance traveled.

Among important factors determining the average miles per gallon of gasoline consumed are the size of the automobile and type of highways.

The increased gasoline consumption which might be expected from the tendency toward larger passenger cars has been mostly off-set by the greatly increased fuel efficiency brought about by the higher compression ratios, better gasoline, and mechanical improvement in automobiles. The significance in this fact, however, lies in the possibility of greatly increasing the miles per gallon of gasoline by sacrificing the size, power, and some of the other conveniences enjoyed in the modern car. Thus, a material increase in the price of gasoline might affect the trend of demand per motor vehicle radically.

*Annual domestic motor-fuel demand and demand per motor vehicle in use 1924–38, with trends 1924–40*

| Year | Domestic motor fuel demand (1,000 barrels) | Motor vehicles in use July 1 | Motor fuel demand per motor vehicle in use (barrels) | | |
|---|---|---|---|---|---|
| | | | Actual | Trends | |
| | | | | 1924–31 trend | Variable trend |
| 1924 | 187, 022 | 16, 022, 000 | 11. 67 | 11. 94 | ---------- |
| 1925 | 226, 329 | 17, 808, 000 | 12. 71 | 12. 65 | ---------- |
| 1926 | 264, 391 | 19, 784, 000 | 13. 36 | 13. 36 | ---------- |
| 1927 | 299, 818 | 21, 297, 000 | 14. 08 | 14. 07 | ---------- |
| 1928 | 332, 033 | 22, 025, 000 | 15. 08 | 14. 77 | ---------- |
| 1929 | 375, 999 | 23, 733, 000 | 15. 84 | 15. 48 | ---------- |
| 1930 | 394, 800 | 24, 710, 000 | 15. 98 | 16. 19 | ---------- |
| 1931 | 403, 418 | 24, 273, 000 | 16. 63 | 16. 90 | ---------- |
| 1932 | 373, 900 | 23, 206, 000 | 16. 11 | 17. 61 | ---------- |
| 1933 | 377, 003 | 22, 745, 000 | 16. 60 | 18. 32 | ---------- |
| 1934 | [1] 410, 339 | 23, 483, 000 | 17. 32 | 19. 02 | 19. 02 |
| 1935 | 434, 810 | 24, 341, 500 | 17. 77 | 19. 73 | 19. 60 |
| 1936 | 481, 606 | 25, 927, 700 | 18. 47 | 20. 44 | 20. 10 |
| 1937 | 519, 352 | 27, 570, 600 | 18. 84 | 21. 15 | 20. 40 |
| 1938 | 521, 657 | 28, 186, 600 | 18. 51 | 21. 86 | 20. 69 |
| 1939 | ---------- | ---------- | ---------- | 22. 57 | 20. 96 |
| 1940 | ---------- | ---------- | ---------- | 23. 27 | 21. 22 |

[1] Demand includes natural gasoline losses from 1934 on. Other figures of the Bureau which do not include these losses in 1934 indicate the domestic demand as 407,106,000 barrels in that year.

### INDEXES OF SEASONAL VARIATION FOR MOTOR-FUEL DEMAND PER MOTOR VEHICLE

Seasonal variation is the most important factor determining the month-to-month change in motor-fuel demand. Any index of seasonal variation to be applied to motor-fuel demand must take into consideration the changes brought about by better highways and improved automobiles that make winter travel more pleasant and less hazardous than it formerly was. In other words, it must be a progressive seasonal index.

October, November, and December have been participating in an increasingly greater part of the year's motor-fuel demand, but February has had a definite downward trend. Whereas in early years January represented the lowest month for daily average demand, this distinction has shifted to February. May has had a downward trend, probably because earlier motoring has shifted spring buying of gasoline from May to earlier months. High consumption for June during the past 3 years has given that month an upward trend which probably will not be permanent.

July and August have had a definite downward trend which has changed the index of seasonal variation from a decided midsummer peak to a rounded dome with little change from June to September.

### THE INFLUENCE OF ECONOMIC CONDITIONS UPON MOTOR FUEL DEMAND PER MOTOR VEHICLE

A definite relationship between economic conditions and motor-fuel demand per motor vehicle is revealed after eliminating the trend and seasonal variations. The relationship is a general one, indicating that motor-fuel demand is responsive to the general movements of business conditions, but it is also responsive to forces in its month-to-month movements that are not associated with the business index. These other factors include weather, speculation, changes in price, changes in transportation rates, changes in tax rates and inconsistencies in export statistics. It is only when business conditions are in a changing state, such as during the past decade, that the business index becomes an important factor in motor-fuel demand.

### THE INFLUENCE OF WEATHER UPON DOMESTIC MOTOR FUEL DEMAND

Because of the difference in weather throughout the country and its varying effect upon motor travel in the several sections of the country, a general index of weather for the whole United States will not show as great a relationship with gasoline consumption as one for a smaller section of the country would. A general index of weather, constructed by weighting the deviations from normal temperature for the various sections of the country by the gasoline consumed therein shows a significant relationship with motor-fuel demand, and the restriction on gasoline consumption becomes intensified as weather becomes extremely cold.

### EXPORTS

The Bureau of Mines calculates the domestic demand for motor fuel by subtracting the exports, as reported by the Bureau of Foreign and Domestic Commerce, from the calculated figure of total demand.

Thus, if near the end of the month any boats are loaded and cleared by a refiner, that cargo will not appear in the stocks for that company and would be indicated as part of the total demand for that month. However, if it had not cleared the Customs office by the end of the month, it would not appear as an export until the succeeding month, in which case the Bureau's calculations for domestic demand would be too high in the first month and too low in the succeeding one. Similar errors would occur if for any reason shipments were not reported by the customs officials until one or more months after they occurred.

A check was made to determine the effect of such discrepancies in exports upon domestic motor-fuel demand for the period 1925–34, inclusive, by correlating abnormal exports with abnormal domestic motor-fuel demand. It is readily apparent that many abnormalities in exports are not caused by erroneous statistics but are merely from some natural cause such as the round trip sailing time of vessels which permits them to be loaded usually twice a month, but only once or as many as three times every third or fourth month. However, if the abnormalities are associated with opposite abnormalities in domestic motor-fuel demand, there is some indication that the abnormalities are not natural.

## SPECULATIVE FACTORS

Among the factors that cause the greatest fluctuation in motor-fuel demand is one group that is not related to the month-to-month changes in gasoline consumption. That is the speculative group, which includes changes caused by actual or anticipated tax changes, changes in transportation costs, and price changes.

With the exception of a few consumers such as bus or truck operators who have storage tanks or can store a few barrels of gasoline, it is usually not practical for the gasoline user to anticipate gasoline cost changes further than to fill up the tank of his automobile. It is different with the retailer and distributor, who can fill their storage tanks to capacity or let their stocks run down to their barest needs. That this is frequently done is clearly reflected in the changes in motor-fuel demand.

Tax changes do not occur frequently, but a tax increase is anticipated by a heavy demand for gasoline just previous to the increase, and is followed by a decline in demand subsequent to the effective date of the increase.

Tax changes in the different States have the same effect upon the motor-fuel demand in the State, and it has frequently been cited erroneously, as proof that an increase in the tax causes a decline in gasoline consumption.

Changes in railroad-freight rates that can be anticipated should have the same effect as changes in tax rates, causing an increase or decrease in demand, whichever is to the advantage of the buyer.

## THE EFFECT OF PRICES ON MOTOR-FUEL DEMAND

The effect of prices on motor-fuel demand is not a simple one. No relationship is indicated between gasoline prices, within the range which has existed in recent years, and gasoline consumption, other than the usual seasonal changes and the joint relationship between economic conditions, motor-fuel demand, and prices.

There is a relationship, however, between price changes and motor-fuel demand. The study of this relationship first requires the selection of the price series to use. There are refinery prices, which differ in various parts of the country but for which it has become customary to recognize the Oklahoma price as representative. There are, in addition, tank-car prices, dealer's prices, tank-wagon prices, posted retail prices, contract retail prices, favored customer retail prices, truck retail prices, and gasoline taxes which in effect increase the price of gasoline.

In general, the price which the dealer pays the refiner is the price which will affect the refinery demand. as he stands to profit or lose much more by changes in price than does the consumer. However, there are times when retail-price changes are sufficient to affect the demand, as in the price war of October and November 1934, when retail prices for 50 cities dropped from 13.55 cents on October 1 to 11.92 cents on November 1, while price declines ranged as high as 7.9 cents in individual cities.[1]

One of the difficulties in correlating price changes with motor-fuel demand is that the effect does not always come in the month in which the price change takes place. The buyer may realize during the first or second month of a decline that the change is abnormal and cut down his storage to a minimum. Further declines in price then do not affect the quantity of gasoline he takes. Storage will then be brought back to normal again after the price has become stable, either over a period of time or possibly suddenly if there is an indication that the price will increase.

Mr. Mapes. What was the cause of those price variations?

Mr. Breakey. That I just read?

Mr. Mapes. Yes.

Mr. Breakey. Just a price war.

Mr. Mapes. Between the different distributors?

Mr. Breakey. Yes.

Mr. Mapes. Over how wide a territory were they distributed?

Mr. Breakey. Why, it was over most of the country. I think that the west coast escaped that price war at that time. It was over most of the country, but probably most intense along the east coast and in New Jersey.

Mr. Mapes. Was it a war between the major companies, or the retail dealers?

Mr. Breakey. Well, it has been some time ago, and I do not recall the details distinctly about that.

Mr. Cole. Mr. Breakey, your problem is largely one, as I understand it, to determine the demand for gasoline.

Mr. Breakey. Yes.

Mr. Cole. How do you go about determining the demand for next month, for instance?

Mr. Breakey. That is part of the paper that I was putting in, that I thought probably you would not want me to read; but I will take that up.

Maybe I might explain it in brief here. I mention about the relationship between business conditions and motor-fuel demand for motor vehicles.

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[1] Retail price changes October–December 1934 in specific cities as reported in the Oil and Gas Journal, January 31, 1935, p. 36.

Mr. COLE. Yes.

Mr. BREAKEY. There is a rather definite relationship there for which I determine the correlation between motor-fuel demand per motor vehicle and business conditions, and from that correlation I get an estimating equation to apply to estimated business conditions. I estimate the business conditions for a short period in advance and apply that estimating equation to get the average demand per motor vehicle, and then multiply that by the number of motor vehicles in use to determine the gasoline consumption.

Mr. PEARSON. In estimating business conditions, Mr. Breakey, what do you use as a basis?

Mr. BREAKEY. Whatever information I can get from people who are forecasting the business conditions.

Mr. PEARSON. I mean as to the conditions with relation to what, a year; or as to what other conditions?

Mr. BREAKEY. I use the Federal Reserve Bank of New York index of production and trade. That is probably about 1 month behind, and then I have to estimate for about 2 or 3 months. I have to estimate the current month and for the months I have to forecast.

Mr. COLE. Take the month of November. The amount now being produced, as I understand, is pretty close to the amount you estimated; is that right?

Mr. BREAKEY. Yes.

Mr. COLE. Of course, you mean by that, the amount that the States allocate to the various fields and wells totals approximately the entire demand which you release to them?

How do you cut this pie between the States? What is the yardstick you use and why do you use one like it? Why give one State more than another? How do you determine how much more Texas shall have than Oklahoma?

Mr. BREAKEY. After we have estimated the amount of motor fuel that will be required, we then break that demand up into the various refining districts of the country. The estimated motor-fuel exports are then added to these demand estimates and the resulting figures are adjusted for anticipated changes in gasoline stocks. We then estimate the amount that will be shipped from one district to another, to determine how much gasoline will be required to be produced in each of the refining districts. We also estimate the amount of natural gasoline that will be used in each of those refining districts, and subtract that from the amount of gasoline to be produced in order to determine the amount of gasoline that will have to be produced from crude oil.

Then we get the amount of crude oil required for runs in each of the various districts by applying an estimated yield for each district and subtract the estimated amount of foreign crude that will be used, which leaves the quantity of crude oil that will be needed in each of the various districts. We base all these estimates upon statistics.

Mr. COLE. You say the foreign crude that will be needed, or that will be used?

Mr. BREAKEY. The amount that will be used.

All of these estimates we base upon statistics and then upon the statistics we receive from the various refiners as to the sources of their crude we estimate how much of that crude for each of the districts will come from each of the various States.

Mr. COLE. Do you allocate a certain amount to one or to another producing field?

Mr. BREAKEY. No; we do not. Our estimate is based upon demand.

Mr. COLE. So that if you allocate to one State so many barrels, as the portion that State should supply in the month of December, say, such is done by the Government, the Federal Government, without any consideration whatsoever as to the production ability of that State.

Mr. BREAKEY. That is right, although, rather than say "allocated," I would like to say we estimate the demand. We really do not feel we are allocating any oil. We just merely are estimating the demand for that oil.

Mr. COLE. Do you have the figures showing, during the last 4 years, where the supply exceeded your estimates of demand?

Mr. BREAKEY. Very recently the supply has been less than the demand as to very recent months.

Mr. COLE. The supply has been less?

Mr. BREAKEY. Yes.

Mr. COLE. Less than the demand?

Mr. BREAKEY. Yes; probably I might illustrate that by a comparison of it.

Mr. COLE. Then what takes care of the difference; storage?

Mr. BREAKEY. Yes.

Mr. COLE. What?

Mr. BREAKEY. That is right. The crude-oil storage, for instance, on August 31, 1938, was 285,000,000 barrels; and on July 31. 1939, 270,000,000 barrels. There had been a decline of 15,000,000 barrels in that time, and then, after the August shut-down, they declined further to 238,000,000 barrels, which indicates that the supply was less than the demand during that period—that year.

Mr. KELLY. Mr. Breakey, getting back to the Illinois situation, what method is being used there now in the way of drilling and spacing of oil wells?

Mr. BREAKEY. I am not familiar with that particular side of that at all.

Mr. KELLY. Do you have any agreement between the companies drilling there?

Mr. BREAKEY. I could not testify on that at all.

Mr. COLE. There is not any authentic information on hand in the Federal Government as to what the operations are in Illinois. I imagine someone in the industry can tell you.

Mr. BREAKEY. It is barely possible that some of the men in the Technical Division might be familiar with that.

Mr. COLE. All right; you may proceed.

Mr. MAPES. What part of the time were your estimates more than the actual demand, and what part were they less than the actual demand?

Mr. BREAKEY. Why, since our figures are based upon the actual statistics, there is usually a little bit of a lag, so that if there is a period where the demand is going up, there is a chance for us to be a little bit behind or a little bit low. If in a period where the demand is falling off, there is a chance for us to be a little bit high.

Mr. MAPES. Your estimates, then, I take it, are based pretty largely on current consumption rather than trying to speculate on what the future consumption is going to be.

Mr. BREAKEY. We necessarily do have to base it principally upon the actual statistics, or actual facts.

Mr. MAPES. At the time?

Mr. BREAKEY. Yes, sir. Have I answered sufficiently the questions now about how we determine the amount of oil from each of the States?

Mr. COLE. I think so.

Mr. MAPES. I have heard at least one State commissioner say that the States could do this work, make the estimates, for themselves if necessary, if they had to, without assistance from the Bureau of Mines. What do you say about that?

Mr. BREAKEY. Why, what a good many of the State commissioners have told me is—well, I might say those of the principal producing States—is that they could not do it. One just explained to me the other day that before they had the recommendations of the Bureau of Mines they had to ask for nominations from each producer or statements of the amount of oil he was going to sell. These were always excessive and gave no indication of the actual demand.

Mr. MAPES. What is your judgment as to whether the State authorities could do it or not?

Mr. BREAKEY. Well, I feel quite a bit the same as the State officials who have spoken to me—that they could not get along without the Bureau of Mines recommendation.

Mr. COLE. Have you ever had any of them tell you that they could get along without the Bureau?

Mr. BREAKEY. No; I have not had them tell me that.

Mr. MAPES. How large an organization do you have to have to get out these estimates?

Mr. BREAKEY. Well, of course, quite a bit of the Division participates in it, in getting up the statistics, but I do most of the detailed work on the forecast, and Mr. White gives considerable of his time to it also. We have two or three persons who actually do the forecasting work, but, of course, as I say, we are dependent upon a good many of the clerks for getting up the statistical background.

Mr. MAPES. The organization devoted to that work is not a very formidable one?

Mr. BREAKEY. No; it is not, but they are now, for instance, engaged in such things as obtaining the crude-oil stocks by locations, which is probably used entirely for this. That is the principal thing it is used for. We have two clerks on that, and there are considerable statistics that have to be gathered to support our recommendations.

Mr. MAPES. Does the industry itself make any recommendations to you with reference to consumer demands?

Mr. BREAKEY. No. Now, I might correct that in this way: We ask for estimates from the industry and use those as a sort of a guide to see whether our own estimates are in line with theirs. We usually find they are pretty much in line, but if they are not in line, we begin to check over our own estimates to find out if we have sources of error in our calculations.

Mr. MAPES. Do the major companies have any men engaged in making the same studies that you are engaged in?

Mr. BREAKEY. Yes.

Mr. MAPES. Engaged in making the same estimates?

Mr. BREAKEY. Yes; a good many of the companies do have men who do forecasting work for their own organization.

Mr. MAPES. Are your ultimate results much different from their findings?

Mr. BREAKEY. There is quite a wide range in their findings. Some of them are very low, and some of them are very high. As a general rule, though, the average will be fairly close to what we have.

### FACTORS INFLUENCING MOTOR-FUEL DEMAND AMONG THE VARIOUS STATES

A different approach to the study of factors that influence motor-fuel demand contemplates an analysis of those causes that are responsible for differences in the demand among the various States. This analysis was also broken down into two groups of factors, those which were responsible for variations in the per capita registrations of automobiles and those which were responsible for variations in the motor-fuel demand per motor vehicle.

Per capita motor-vehicle registrations range from a low of 0.09 in Alabama to a high of 0.34 in Nevada. Various factors were tested to determine their influence upon registrations, they being per capita wealth, miles of improved highway per motor vehicle, density of population, percentage of Negro population, average winter temperature, automobile fees and insurance per motor vehicle, and percentage of trucks in total registrations. There are other factors that are difficult to express statistically or are so interrelated with different factors that they cannot be measured to advantage, such as the increased cost of new cars in areas distant from the factories, which is offset by differences in sales taxes on new cars in various States; migration of unemployed people by automobile to warmer climates in winter, who then sell their automobiles on the second-hand market—this is particularly noticeable in California and Florida; and the transportation of used automobiles from places where the price is low to places where the price is high, such as the movement during the depression years of automobiles from Michigan to other States.

A correlation study of the factors upon which per capita registration of motor vehicles depended mostly among the various States indicated that per capita wealth is most important. The percentage of Negro population, which is highly correlated with wealth, was the next most important factor, having an added influence independent of its relationship to wealth.

### FACTORS AFFECTING MOTOR-FUEL DEMAND PER MOTOR VEHICLE

Either of two series of compilations may be used to represent motor-fuel demand. The compilations of the American Petroleum Institute represent the total demand, including the gasoline used for nonautomotive purposes, while those of the Bureau of Public Roads represent the net demand after the deduction of gasoline upon which the tax was exempted or refunded because of nonautomotive uses. It would seem that the latter one would be the more satisfactory, because the presence of the nonautomotive fuel in the demand statistics should distort the influence of the factors. However, examination of this series revealed that it was not as satisfactory as the other. Some of the States, including Florida in the extreme South, do not grant any refunds of gasoline taxes, while three of the States which have the largest refunds, North Dakota, South Dakota, and Montana, are in the extreme North. These extremely large deductions result in a very low gasoline consumption per automobile, but it is not likely that all of the gasoline upon which the tax is refunded is used for nonautomotive purposes. This incidental relationship between climate and gasoline-tax refunds gives the climatic factor an exaggerated importance. This can be corrected satisfactorily by using the total demand and including a factor of the percentage of total gasoline-tax collections refunded.

Winter temperature, represented by the average temperature from December to April, is the most important single factor determining the gasoline consumption per motor vehicle. This can readily be understood, as the severe winters of the North keep many cars off the roads and even relegate some to the garages for months. However, the importance of this factor has been changing. Paved, all-weather highways, snow clearance, closed and heated cars, along with other aids, have increased highway travel in the winter, as is indicated by a study of motor traffic over toll bridges, which shows the percentage of the traffic for the winter months to be increasing, and the study on seasonal variation in the forepart of this testimony.

The next most important factor is nonautomotive gasoline consumption, represented by the percentage of gasoline tax refunded. One of the difficulties in this factor is that some of the States allow little or no refunds or exemptions, so the importance of nonautomotive gasoline consumption cannot be accurately determined. Among such States are Alabama, Connecticut, Florida, Georgia, Kentucky, Louisiana, Pennsylvania, Tennessee, Vermont, and Wyoming. It is not possible to assume that these States where no refund is allowed consume a comparable amount of gasoline, because there is a tendency, especially where the tax is heavy, to use a high-flash tractor fuel. The differential between this fuel price and that of gasoline plus the tax is often greater than the cost of the fuel.

Closely following in importance is the percentage of the total registrations represented by trucks. Average consumption per mile as well as average consumption per vehicle is greater for trucks than for passenger cars,[1] so it is natural to expect the States having the larger percentage of trucks to have a greater consumption per vehicle.

Although some studies have indicated that as the population density increased the annual miles of motor traffic also increased, many persons contended that in the rural areas the average trip per motor vehicle was longer and that motor vehicles were used more frequently than in the urban areas, where an owner could not use his automobile so much because of traffic and parking difficulties. This study indicates that as population density increases, the gasoline consumption per automobile also increases. It will be recalled that this factor contributed some influence toward per capita registrations of motor vehicles, thus having a double influence on gasoline consumption.

Fees and insurance represent another factor which also influences motor-vehicle registrations. Its influence in gasoline consumption per vehicle is probably due to eliminating automobiles that are not used sufficiently to warrant this cost. Thus an automobile purchaser who can get but a small allowance for his old car often considers it worth considerably more to him than the trade-in allowance, and it probably

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[1] See Public Roads, April 1933, p. 30.

is from the standpoint of the mileage it has and from its upkeep. This attitude often results in the owner deciding to keep the car for extra transportation if the registration cost is small. However, a high registration fee or costly insurance premiums, or both, will act as a deterrent on keeping this extra car.

Per capita wealth, which was extremely important in determining the per capita registrations, seems to have but very small influence in determining the gasoline consumption per motor vehicle. At first thought this might seem to indicate that the wealthy person did not use his car more than the poorer one. It might also imply that no more gasoline was consumed by a large car than by a small one. This is obviously not so, as the difference in miles per gallon between a large car and a small one would cause greater consumption. The reason probably lies in the fact that in considering the gasoline consumption per automobile there has been automatically selected only a certain proportion of the population for consideration. As was shown in the earlier part of this study, wealth is an important factor in determining who is to have an automobile. Thus, in the States with low per capita wealth the poor people are eliminated as car owners, which automatically creates a new class with a higher per capita wealth as consumers of gasoline. It is this fact that makes it appear that per capita wealth has such small influence on motor-fuel demand.

No significant relation could be found between the price of gasoline and motor-fuel demand in either this study or in a time analysis of the factors influencing the month-to-month fluctuations in motor-fuel demand. This, of course, does not mean that there is no relationship. It merely means that within the range of the gasoline price during the period under consideration no influence has been apparent in those studies.

It is obvious that as the price of gasoline rises in relation to other prices, drivers will be forced to obtain a greater mileage per gallon, probably by being satisfied with less powerful engines and by stricter observance of efficient operation; and, in addition, they will probably curtail their driving even to the elimination of the automobile entirely in some cases.

Although gasoline taxes are really part of the price, it is possible that a separate study might show some significant relationship to demand, not that taxes actually affect the demand, but it might indicate that the magnitude of the tax has some effect upon the bootlegging of gasoline and claims for refunds.

Considering that the State and Federal gasoline taxes are now approaching $1,000,000,000 per year, there is a considerable dearth of knowledge as to what effect they have upon gasoline consumption, upon tax evasion, and upon other economic forces.

## HIGHWAY MILEAGE

Although the increasing mileage of improved streets and highways probably has been the most important factor in the mounting gasoline consumption per motor vehicle during the past decade, practically no correlation is indicated between the mileage per motor vehicle of high-type-surface highways and gasoline consumption per motor vehicle.

Even though this relationship does not consider the street improvements within cities, it seems that the class of roads a State possesses should have a greater influence on gasoline consumption than that indicated. Several considerations probably enter into this low coefficient, the most important of which is lack of uniformity in the statistics of highway mileage. There is no distinction between a recently built modern paved highway and a poorly constructed highway so badly neglected and depreciated that it is a poorer route for travel than a well-kept gravel road. Thus, one of the States that ranks near the top in high-type-surfaced highway mileage per motor vehicle has the reputation of having very poor roads. Again there is no distinction between a wide, straight, modern highway and a crooked, narrow, round-topped pavement handed down from the horse-and-buggy days.

### SUMMARY

Factors that affect motor-fuel demand can be classified under two heads, those which affect the number of motor vehicles in use, and those which affect the gasoline consumption per motor vehicle.

Per capita wealth and the percentage of Negro population are the factors which have the greatest influence on the first of these, followed in importance by density of population and automobile insurance and fees.

Among the factors influencing the gasoline consumption per automobile, climate, represented by the average winter temperature, is the most important. Nonautomotive gasoline consumed, as represented by gasoline tax refunds, was the second most important factor, percentage of trucks to total motor vehicles, population density, and automobile fees and insurance follow in importance. The per capita wealth of a State, gasoline price—within the range of the past 10 years—and mileage of high-type-surfaced highways, without regard to age, width, or other differences within this class, show but little influence upon the gasoline consumption per automobile.

### MOTOR-FUEL STOCKS

Motor-fuel stocks enter the forecasting of crude-oil requirements from two different angles; their relation to motor-fuel demand, and the consideration of proper stock changes.

It has already been suggested that speculative buying is one of the most important factors that causes the difference between motor-fuel consumption and motor-fuel demand.

Motor-fuel demand is calculated by adding or subtracting the change in motor-fuel stocks to or from motor-fuel production plus imports. If the Bureau of Mines had statistics upon all motor-fuel stocks in the country, the demand and consumption would coincide, but stock statistics of the Bureau are limited to refinery, pipe line, and bulk terminal stocks, the latter being those stocks held at the large marine terminals with storage sufficient to accommodating ship cargoes. Thus, stocks held by the retailers and distributors for town and city supply, which are quite large, are not included in the Bureau's figures.

It is questionable, though, whether statistics of motor-fuel consumption would be as desirable as those of demand. While there are many persons who would find consumption statistics extremely useful, the oil industry is more interested in the wholesale, or refinery demand, considering the refinery in its broader sense of including pipe lines and bulk-terminal plants. This is the demand that the industry must plan on meeting and which must regulate their operations.

In addition to these sudden speculative changes being present in motor-fuel demand, wholly unrelated to gasoline consumption, the seasonal variation in the demand is also different from the seasonal variation in the consumption. The dealer must anticipate needs by buying in advance for the heavy-consuming season, making the spring demand heavier than the actual consumption. Then by permitting stocks to be depleted as winter approaches, to cover only the needs of the curtailed sales, fall demand is less than the actual consumption. A practice in the north which tends to offset this is that of storing the winter supply of oils before the freezing of the waterways stop boat and barge transportation.

The question of the motor-fuel stock change that should enter into the forecast depends upon the seasonal variation of stocks and the minimum quantity of stocks that will keep the industry functioning upon a smooth basis.

The days' supply of gasoline is the easiest form in which to study this relationship between stocks and demand, this being calculated from the stocks at the beginning of the month divided by the total demand, domestic, plus exports, for the month. These figures indicate that as a practical matter stocks have been increasing faster than demand during the past 4 years.

*Days' supply of motor fuel on hand in the United States at end of month, 1936–38* [1]

| Month | 1936 | | | 1937 | | | 1938 [2] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Finished gasoline | Natural gasoline | Total motor fuel | Finished gasoline | Natural gasoline | Total motor fuel | Finished gasoline | Natural gasoline | Total motor fuel |
| January | 56.1 | 3.9 | 60.0 | 52.0 | 3.2 | 55.2 | 61.9 | 3.9 | 65.8 |
| February | 53.8 | 3.4 | 57.2 | 51.5 | 3.1 | 54.6 | 58.8 | 3.5 | 62.3 |
| March | 48.7 | 3.2 | 51.9 | 48.2 | 3.1 | 51.3 | 53.5 | 3.4 | 56.9 |
| April | 46.1 | 3.5 | 49.6 | 46.6 | 3.4 | 50.0 | 51.8 | 3.9 | 55.7 |
| May | 41.4 | 3.5 | 44.9 | 42.0 | 3.4 | 45.4 | 46.2 | 3.7 | 49.9 |
| June | 38.3 | 3.6 | 41.9 | 39.1 | 3.6 | 42.7 | 44.2 | 4.1 | 48.3 |
| July | 35.8 | 3.6 | 39.4 | 36.6 | 4.0 | 40.6 | 39.4 | 4.2 | 43.6 |
| August | 34.0 | 3.5 | 37.5 | 34.5 | 4.1 | 38.6 | 39.1 | 4.8 | 43.9 |
| September | 34.1 | 3.3 | 37.4 | 36.7 | 3.8 | 40.5 | 38.5 | 5.0 | 43.5 |
| October | 36.2 | 3.1 | 39.3 | 39.9 | 3.5 | 43.4 | 39.2 | 4.1 | 43.3 |
| November | 39.2 | 3.0 | 42.2 | 47.2 | 3.8 | 51.0 | 42.2 | 3.8 | 46.0 |
| December | 47.6 | 3.4 | 51.0 | 56.6 | 3.9 | 60.5 | 49.3 | 3.6 | 52.9 |

[1] Stocks divided by the daily average total demand (domestic demand plus exports) for succeeding month.

[2] Subject to revision.

Motor-fuel stocks may be classified as fixed and variable. The fixed are those stocks which are unavailable for current trade, and include tank bottoms, pipe-line fill and other intransit stocks, and working stocks. The principal item in the variable stocks is the seasonal factor. During the cold weather when motor-fuel demand is low, stocks are built up to meet the heavy summer demand. This evens the year-around demand upon the refinery and makes employment steadier. The demand for heating oil frequently spurs the winter activity, causing usually large runs of crude oil and results in gasoline stocks being accumulated to an unreasonably high level. Such excessive stocks are burdensome both from the standpoint of the refiner who has his current assets tied up in a product for which there is not a present market and from the standpoint of storage capacity.

### THE DEMAND FOR FUEL OIL

There are two types of fuel oil—gas oil and distillate fuel oils, and residual fuel oil. The first type represents those products ranging in gravity between kerosene and lubricants, while the residual fuel oil, as its name implies, is the residuum after the removal of the wax distillate or lubricating oil stock, the residue from the cracking operations and from other special operations.

Household heating oil is the first type and is of sufficient importance from a convenience standpoint that it is likely to be competitive with gasoline until the price of gasoline is so high that there is too much differential between the cost of heating by coal and the cost of heating by oil to support the demand for heating oil.

Diesel oil, used among other things, for marine purposes, railway locomotives, stationary engines, and automobiles, is another preferential use of distillate fuel oil that will persist in competition with gasoline.

Residual fuel oil is usually considered as a byproduct, and outside of its use by naval vessels could probably be replaced by coal in most of its uses.

Provision is usually made in the forecast for distillate fuel-oil requirements by changes in the gasoline yield and by changes in gasoline stocks. The gasoline yield usually declines slightly during the winter months because of the running of heavier types of crudes to produce heating oils, and curtailed cracking operations. More gasoline is produced in the winter than is necessary to supply the current demand, and if the demand for heating oil is large the resulting refining operations intensify the excess production of gasoline. This usually results in very large accumulation of gasoline stocks. The Bureau, in addition to changing the estimated yield of gasoline, also provides for fuel oil requirements by anticipating reasonable changes in gasoline stocks.

Mr. COLE. Mr. Breakey, can you give us an idea as to how much longer it will take to complete your statement? I do not want to hurry you but I want to get an estimate on our time.

Mr. BREAKEY. Just a few minutes.

Mr. COLE. I do not want to hurry you.

Mr. BREAKEY. I am at conclusions now.

### CONCLUSIONS REGARDING FACTORS INFLUENCING DOMESTIC MOTOR-FUEL DEMAND

Domestic motor-fuel demand differs from motor-fuel consumption in that there are many factors that affect the demand for motor fuel at the refinery which are not associated with the consumption. For the most part, the factors which influence the consumption, including motor vehicles in use, the trend of motor-fuel demand per motor vehicle, seasonal variation, and an index of economic conditions, are not greatly erratic and can be predicted to a fair degree of accuracy.

Other factors, including weather, price changes, and inconsistencies in export data, cannot be predicted sufficiently close to use for forecasting motor-fuel demand. These factors cause wide fluctuations in month-to-month motor-fuel-demand statistics, aside from those caused by the predictable factors, and there is probably little hope of improving forecasts to allow for them.

Other factors, such as changes in tax rates and transportation costs, can usually be anticipated and a partial allowance made for their effect upon demand. The infrequent occurrence of these factors, however, make it difficult to estimate accurately their effect.

This difficulty is even more evident in attempts to make allowance for such things as droughts, floods, fires, fairs, and other unusual happenings, the general effect of which as far as they are predictable are usually provided for in the business index, and which sometimes have the opposite effect upon motor-fuel demand from that which is expected. A drought, for instance, may cause a second crop to be planted, requiring double plowing, accompanied by additional need for tractor gasoline, or it may give the farmer an opportunity to let his land lie fallow for the season while he takes an automobile trip. A flood, although it washes out highways and restricts traffic in the vicinity of the flood, also demands a certain amount of relief travel by boats, airplanes, and automobiles, and a part of the traffic that is lost to that area is merely diverted to another area.

The simplest method of using the predictable factors for forecasting domestic motor-fuel demand is to reduce the statistics to a demand per motor vehicle. Trend and seasonal variation are eliminated from this, and the result correlated with an index of business conditions.

The correlation of these figures yields a regression, or estimating equation. This is applied in forecasting by estimating the index of business conditions. This is comparatively easy for short periods in advance because the movement of the index is not of such magnitude as to cause its effect upon motor-fuel demand to vary greatly. The application of the regression equation to the index of business conditions and the trend factor measures the statistical influence that these factors have upon the "ratio to trend," and the estimated ratio to trend is obtained by combining this product with the index of seasonal variation.

The trend of motor-fuel demand per million motor vehicles is then multiplied by the estimated ratio to trend, the product of which is multiplied by the estimated number of motor vehicles in use, determined by the method described earlier, to obtain the daily average motor-fuel demand. The product of this figure by the number of days in the month is the estimated motor-fuel demand for the month.

The standard error is 2.97, expressed in terms of the net ratio to trend. Although the number of motor vehicles and the index of seasonal variations intervene between the net ratio and the monthly motor-fuel demand so that this standard error cannot be applied accurately to the monthly motor-fuel demand, we can at least get an approximation of its significance. It indicates that in spite of the fluctuations caused by the unpredictable factors, about two-thirds of the estimates of motor-fuel demand based upon this correlation will fall within 2.97 percent of the actual, and about 95 percent of the estimates will fall within twice the standard error, or 5.94 percent of the actual.

# APPENDIX

## STATISTICAL TABLES RELATING TO MOTOR FUEL AND OTHER REFINED PRODUCTS

[Source: Bureau of Mines]

### *Runs to stills and production at refineries of the various refined products, 1934–38*

[Thousands of barrels, except as otherwise indicated]

| | 1934 | 1935 | 1936 | 1937 | 1938 [1] |
|---|---|---|---|---|---|
| Input: | | | | | |
| Crude petroleum: | | | | | |
| Domestic | 860, 776 | 933, 659 | 1, 034, 637 | 1, 157, 444 | 1, 138, 828 |
| Foreign | 34, 860 | 32, 131 | 33, 933 | 25, 996 | 26, 187 |
| Total crude petroleum | 895, 636 | 965, 790 | 1, 068, 570 | 1, 183, 440 | 1, 165, 015 |
| Natural gasoline [2] | 28, 162 | 31, 025 | 33, 817 | 39, 381 | 39, 961 |
| Total input | 923, 798 | 996, 815 | 1, 102, 387 | 1, 222, 821 | 1, 204, 976 |
| Output: | | | | | |
| Gasoline | 416, 932 | 457, 842 | 504, 811 | 559, 141 | 555, 850 |
| Kerosene | 53, 855 | 55, 813 | 56, 082 | 65, 308 | 64, 580 |
| Gas oil and distillate fuel oils | 94, 972 | 100, 235 | 125, 906 | 146, 706 | 151, 774 |
| Residual fuel oils | 240, 381 | 259, 826 | 287, 968 | 312, 064 | 294, 972 |
| Lubricants | 26, 373 | 27, 853 | 30, 927 | 35, 321 | 30, 826 |
| Wax | 1, 674 | 1, 608 | 1, 689 | 1, 863 | 1, 555 |
| Coke | 6, 500 | 7, 290 | 6, 891 | 6, 533 | 8, 011 |
| Asphalt | 15, 623 | 17, 133 | 21, 278 | 23, 001 | 24, 159 |
| Still gas | 44, 391 | 51, 184 | 57, 046 | 64, 218 | 62, 410 |
| Wax thousands of pounds | 468, 720 | 450, 240 | 472, 920 | 521, 640 | 435, 400 |
| Coke thousands of short tons | 1, 300. 0 | 1, 458. 0 | 1, 378. 2 | 1, 306. 6 | 1, 602. 2 |
| Asphalt do | 2, 840. 5 | 3, 115. 1 | 3, 868. 8 | 4, 182. 0 | 4, 392. 4 |
| Still gas millions of cubic feet | 169, 479 | 197, 220 | 226, 466 | 241, 981 | 236, 943 |
| Road oil | 6, 210 | 6, 030 | 7, 398 | 8, 087 | 7, 788 |
| Other finished products | 1, 872 | 1, 888 | 2, 148 | 2, 382 | 1, 921 |
| Crude gasoline (net) | [3] 3, 007 | 1, 032 | 486 | [3] 128 | [3] 1, 616 |
| Other unfinished oils (net) | 1, 949 | [3] 2, 412 | [3] 8, 962 | [3] 7, 931 | [3] 4, 450 |
| Shortage | 16, 073 | 11, 493 | 8, 719 | 6, 256 | 7, 196 |
| Total output | 923, 798 | 996, 815 | 1, 102, 387 | 1, 222, 821 | 1, 204, 976 |

[1] Subject to revision.

[2] Includes natural gasoline run through pipe lines in California.

[3] Negative quantity; represents net excess of unfinished oils rerun over unfinished oils produced.

### *Summary of percentage yields of refined products in the United States, 1932–38*

[Computed on total crude runs to stills]

| Product | 1932 | 1933 | 1934 | 1935 | 1936 | 1937 | 1938 [1] |
|---|---|---|---|---|---|---|---|
| Finished products: | | | | | | | |
| Gasoline [2] | 44. 7 | 43. 7 | 43. 4 | 44. 2 | 44. 1 | 43. 9 | 44. 3 |
| Kerosene | 5. 3 | 5. 7 | 6. 0 | 5. 8 | 5. 2 | 5. 5 | 5. 5 |
| Gas oil and distillate fuel oils | 8. 5 | 9. 2 | 10. 6 | 10. 4 | 11. 8 | 12. 4 | 13. 0 |
| Residual fuel oils | 27. 5 | 27. 6 | 26. 8 | 26. 9 | 27. 0 | 26. 4 | 25. 3 |
| Lubricants | 2. 7 | 2. 8 | 2. 9 | 2. 9 | 2. 9 | 3. 0 | 2. 6 |
| Wax | . 2 | . 2 | . 2 | . 2 | . 2 | . 2 | . 1 |
| Coke | 1. 1 | . 9 | . 7 | . 7 | . 6 | . 6 | . 7 |
| Asphalt | 1. 7 | 1. 5 | 1. 8 | 1. 8 | 2. 0 | 1. 9 | 2. 1 |
| Road oil | . 8 | . 6 | . 7 | . 6 | . 7 | . 7 | . 7 |
| Still gas | 5. 0 | 5. 2 | 5. 0 | 5. 3 | 5. 3 | 5. 4 | 5. 4 |
| Other | . 2 | . 2 | . 2 | . 2 | . 2 | . 2 | . 2 |
| Unfinished products: | | | | | | | |
| Gasoline | [3] . 2 | . 5 | [3] . 3 | . 1 | (4) | (3 4) | [3] . 1 |
| Other | | | . 2 | [3] . 3 | [3] . 8 | [3] . 7 | [3] . 4 |
| Shortage | 2. 5 | 1. 9 | 1. 8 | 1. 2 | . 8 | . 5 | . 6 |
| | 100. 0 | 100. 0 | 100. 0 | 100. 0 | 100. 0 | 100. 0 | 100. 0 |

[1] Subject to revision.

[2] Based on total gasoline production less natural gasoline used.

[3] Negative percentage; represents excess percentage rerun over percentage produced.

[4] Less than 0.1 percent.

*Comparative analyses of statistics for the major refined products, 1934–38*

[Thousands of barrels, except as otherwise indicated]

| | 1934 | 1935 | 1936 | 1937 | 1938 [1] |
|---|---|---|---|---|---|
| **Motor fuel:** | | | | | |
| Production | 423, 801 | 468, 021 | 516, 266 | 571, 727 | 567, 905 |
| Imports | 1 | ---------- | 78 | 144 | 79 |
| Exports | 24, 686 | 30, 613 | 28, 646 | 38, 306 | 50, 198 |
| Stocks, end of period | 51, 747 | 54, 345 | 60, 437 | 74, 650 | 70, 779 |
| Domestic demand | 407, 106 | 434, 810 | 481, 606 | 519, 352 | 521, 657 |
| **Kerosene:** | | | | | |
| Production | 53, 855 | 55, 813 | 56, 082 | 65, 308 | 64, 580 |
| Exports | 9, 781 | 6, 651 | 6, 936 | 8, 886 | 7, 513 |
| Stocks, end of period | 6, 398 | 7, 915 | 5, 633 | 7, 083 | 7, 799 |
| Domestic demand | 44, 234 | 47, 645 | 51, 428 | 54, 972 | 56, 351 |
| **Gas oil and distillate fuel oils:** | | | | | |
| Production | 94, 972 | 100, 235 | 125, 906 | 146, 706 | 151, 774 |
| Imports | (2) | 15 | 182 | 17 | ---------- |
| Exports | (2) | 16, 249 | 20, 448 | 30, 129 | 29, 903 |
| Stocks, end of period | 21, 957 | 19, 930 | 22, 813 | 22, 566 | 27, 873 |
| Domestic demand | (2) | 86, 028 | 102, 757 | 116, 841 | 116, 564 |
| **Residual fuel oils:** | | | | | |
| Production | 240, 381 | 259, 826 | 287, 968 | 312, 064 | 294, 972 |
| Transfers [3] | 8, 382 | 13, 067 | 15, 732 | 17, 423 | 10, 660 |
| Imports | (2) | 16, 115 | 18, 801 | 22, 114 | 20, 985 |
| Exports | (2) | 12, 699 | 14, 435 | 15, 304 | 17, 728 |
| Stocks, end of period | [4] 88, 440 | [4] 84, 054 | [4] 84, 236 | [4] 95, 019<br>[5] 81, 507 | 97, 746 |
| Domestic demand | (2) | 280, 695 | 307, 884 | 325, 514 | 292, 650 |
| **Lubricants:** | | | | | |
| Production | 26, 373 | 27, 853 | 30, 927 | 35, 321 | 30, 826 |
| Imports | 2 | 1 | 4 | 7 | 7 |
| Exports | 7, 660 | 8, 499 | 8, 691 | 10, 975 | 9, 402 |
| Stocks, end of period | 7, 331 | 7, 025 | 6, 942<br>[5] 6, 482 | 7, 512 | 7, 695 |
| Domestic demand | 18, 484 | 19, 661 | 22, 323 | 23, 323 | 21, 248 |
| **Wax (thousands of pounds):** | | | | | |
| Production | 468, 720 | 450, 240 | 472, 920 | 521, 640 | 435, 400 |
| Imports | 37, 292 | 19, 557 | 16, 669 | 36, 929 | 28, 927 |
| Exports | 198, 958 | 229, 905 | 187, 342 | 231, 723 | 201, 919 |
| Stocks, end of period | 136, 136 | 114, 675 | 115, 434 | 144, 992 | 129, 340 |
| Domestic demand | 240, 035 | 261, 353 | 301, 488 | 297, 288 | 278, 060 |
| **Coke (thousands of short tons):** | | | | | |
| Production | 1, 300. 0 | 1, 458. 0 | 1, 378. 2 | 1, 306. 6 | 1, 602. 2 |
| Exports | 114. 3 | 133. 5 | 124. 6 | 164. 3 | 155. 6 |
| Stocks, end of period | 405. 1 | 388. 9 | 389. 4 | 378. 6 | 707. 5 |
| Domestic demand | 1, 508. 1 | 1, 340. 7 | 1, 253. 1 | 1, 153. 1 | 1, 117. 7 |
| **Asphalt (thousands of short tons):** | | | | | |
| Production | 2, 840. 5 | 3, 115. 1 | 3, 868. 8 | 4, 182. 0 | 4, 392. 4 |
| Imports | 15. 6 | 54. 0 | 21. 6 | 34. 1 | 33. 2 |
| Exports | 239. 9 | 232. 8 | 211. 4 | 45. 5 | 50. 2 |
| Stocks, end of period | 339. 2 | 429. 7 | 364. 2 | 557. 4<br>[5] 566. 1 | 480. 9 |
| Domestic demand | 2, 536. 5 | 2, 845. 8 | 3, 744. 5 | 3, 977. 4 | 4, 460. 6 |
| **Road oil:** | | | | | |
| Production | 6, 210 | 6, 030 | 7, 398 | 8, 087 | 7, 788 |
| Stocks, end of period | 664 | 732 | 851 | 984<br>[5] 667 | 680 |
| Domestic demand | 6, 378 | 5, 962 | 7, 279 | 7, 954 | 7, 775 |
| **Other finished products:** | | | | | |
| Production | 1, 872 | 1, 888 | 2, 148 | 2, 382 | 1, 941 |
| Imports | 316 | 150 | ---------- | ---------- | ---------- |
| Exports | 47 | 76 | 71 | 101 | 112 |
| Stocks, end of period | 231 | 220 | 198 | 230 | 263 |
| Domestic demand | 2, 126 | 1, 973 | 2, 099 | 2, 249 | 1, 776 |

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[1] Subject to revision.

[2] Figures not available.

[3] Net transfers from crude oil to fuel oil in California.

[4] California heavy crude included.

[5] For comparison with succeeding year.

*Production and consumption of gasoline in the United States, 1936–38, by States*

[Thousands of barrels]

| State | 1936 | | 1937 | | 1938 | |
|---|---|---|---|---|---|---|
| | Production | Consumption [1] | Production | Consumption [1] | Production [2] | Consumption [1] |
| Alabama | (3) | 4,872 | (3) | 5,378 | (3) | 5,483 |
| Arizona | | 2,277 | | 2,473 | | 2,434 |
| Arkansas | 2,768 | 3,672 | 3,006 | 3,908 | 3,028 | 4.050 |
| California | 76,942 | 39,371 | 79,967 | 41,853 | 77,528 | 41,722 |
| Colorado | 729 | 4,875 | 752 | 5,263 | 1,170 | 5,404 |
| Connecticut | | 7,129 | | 7,784 | | 7,606 |
| Delaware | | 1,204 | | 1,302 | | 1,323 |
| District of Columbia | | 3,029 | | 3,262 | | 3,316 |
| Florida | | 7,452 | | 7,831 | | 8,062 |
| Georgia | [4] 995 | 7,267 | [5] 5,332 | 7,899 | [5] 4,990 | 8,066 |
| Idaho | | 2,092 | | 2,253 | (6) | 2,255 |
| Illinois | 23,155 | 28,379 | 26,407 | 30,794 | 28,309 | 31,782 |
| Indiana | 40,227 | 13,780 | 42,940 | 15,091 | 40,737 | 15,046 |
| Iowa | | 10,957 | | 11,807 | | 12,574 |
| Kansas | [7] 30,710 | 10,722 | [7] 32,481 | 11,195 | [7] 31,231 | 11,167 |
| Kentucky | [8] 4,053 | 5,436 | [8] 4,287 | 5,996 | [8] 4,729 | 6,109 |
| Louisiana | [3] 25,724 | 5,152 | [3] [9] 26,405 | 5,679 | [3] 24,791 | 5,899 |
| Maine | | 3.203 | | 3,463 | | 3,449 |
| Maryland | 4,809 | 5 839 | (5) | 6,433 | (5) | 6,475 |
| Massachusetts | [10] 4,863 | 15,661 | [10] 5,586 | 16,583 | [10] 4,625 | 16,432 |
| Michigan | 4,653 | 23,709 | 5,672 | 26,443 | 6,822 | 25,094 |
| Minnesota | | 11 449 | | 12,140 | | 12,612 |
| Mississippi | | 4,069 | | 4,519 | | 4,616 |
| Missouri | (7) | 13,514 | (7) | 14,060 | (7) | 14,373 |
| Montana | 1,678 | 2,655 | 2,317 | 2 760 | 2,562 | 2,824 |
| Nebraska | (11) | 5,485 | (11) | 5,455 | (6) | 5,489 |
| Nevada | | 815 | | 890 | | 948 |
| New Hampshire | | 1,926 | | 2,031 | | 2,028 |
| New Jersey | 26,388 | 17,750 | 30,302 | 19,538 | 26,214 | 19,748 |
| New Mexico | [12] 2,632 | 1,806 | [12] 3,148 | 2,111 | [12] 3,100 | 2,145 |
| New York | 5,858 | 40,996 | 5,833 | 43,228 | 5,515 | 42,910 |
| North Carolina | | 8,289 | | 9,272 | | 9,546 |
| North Dakota | | 2,652 | | 2,899 | | 3,031 |
| Ohio | 19,520 | 28,642 | 22,323 | 31,161 | 21,517 | 30,448 |
| Oklahoma | 35,122 | 8,808 | 37,095 | 9,284 | 34,488 | 9,564 |
| Oregon | | 5,138 | | 5,401 | | 5,469 |
| Pennsylvania | 43.031 | 30,554 | 46,164 | 33,749 | 43.353 | 33,419 |
| Rhode Island | (10) | 2,818 | (10) | 2,913 | (10) | 2,881 |
| South Carolina | (4) | 3,903 | (5) | 4,480 | (5) | 4,656 |
| South Dakota | (11) | 2,700 | (11) | 2,708 | (6) | 3,080 |
| Tennessee | (8) | 6,341 | (8) | 6,355 | (8) | 6,717 |
| Texas | 142,675 | 26,362 | 170,279 | 29,054 | 182.427 | 30,245 |
| Utah | (12) | 1,985 | (12) | 2,169 | (12) | 2,209 |
| Vermont | | 1,429 | | 1,567 | | 1,531 |
| Virginia | | 7,537 | | 8,158 | | 8,456 |
| Washington | | 7,607 | | 7,964 | | 8,046 |
| West Virginia | 1,474 | 4,317 | 1,598 | 4,672 | 1,627 | 4,532 |
| Wisconsin | | 12.012 | | 12.883 | | 12,916 |
| Wyoming | [11] 6,805 | 1,397 | [11] 7,247 | 1,524 | [6] 7,087 | 1,478 |
| Total United States | 504,811 | 469,034 | [9] 559,141 | 505,635 | 555,850 | 509.665 |

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[1] American Petroleum Institute.
[2] Subject to revision.
[3] Alabama included with Louisiana.
[4] South Carolina included with Georgia.
[5] South Carolina and Maryland included with Georgia.
[6] Idaho, Nebraska, and South Dakota included with Wyoming.
[7] Missouri included with Kansas.
[8] Tennessee included with Kentucky.
[9] Revised figures.
[10] Rhode Island included with Massachusetts.
[11] Nebraska and South Dakota included with Wyoming.
[12] Utah included with New Mexico.

That concludes my testimony.

Mr. **Cole.** All right; thank you very much.

Mr. **Breakey.** You wanted me to file, I understand, this with the reporter?

Mr. **Cole.** Yes; that may be inserted in the record at this point.

Mr. **Breakey.** Thank you very much.

Mr. **Cole.** Mr. Redfield.

## STATEMENT OF ARTHUR H. REDFIELD, ECONOMIC ANALYST, BUREAU OF MINES

Mr. REDFIELD. Mr. Chairman and members of the committee, let me identify myself as Arthur H. Redfield, economic analyst, Bureau of Mines, now supervising economist in charge of the International Petroleum Section, Petroleum Economics Division; for 19 years in the service of the Federal Government I have been studying petroleum, chiefly in its international phases.

I am a graduate of George Washington University, from which I received the degree of bachelor of arts in 1913 and master of science in geology in 1925. I am now a candidate for the degree of doctor of philosophy at the American University, and expect to receive my degree in June 1940. I trust that is sufficient identification.

I have a prepared statement, but I shall read only a few significant sentences from it.

Mr. COLE. Am I correct in stating that, so far as the hearing in 1934 is concerned, that pages 145 to 165 of part 1 have direct reference to the report you are making today?

Mr. REDFIELD. Yes, sir; the present report would simply attempt to bring those statistics down to date.

Mr. COLE. The pages I have just mentioned?

Mr. REDFIELD. Yes, sir.

Mr. COLE. All right, sir.

Mr. REDFIELD. Five years ago imports of mineral oils into the United States were subject to an officially prescribed quota, through the Petroleum Code under the authority of the National Industrial Recovery Act. The removal of this official regulation of the quantities imported by the decision of the United States Supreme Court in the *Schechter case* left imports of mineral oils subject only to the economic effects of the excise taxes embodied in the Revenue Act of 1932. The results of this change have been unimportant; while the total quantities of foreign oils received in continental United States have increased, the proportion to the total demand, domestic and foreign, has declined.

The papers have just announced the signing of a reciprocal trade agreement with Venezuela, which has the effect of reducing by half these excise taxes on imported oils up to an amount equivalent to 5 percent of the total runs to stills in the United States.

Mr. COLE. Right at that point, to enlarge upon that observation a little bit, am I correct in stating that the announcement of the State Department yesterday, explaining the significance of the quota arrangement, pointed out that the total quantity of crude oil processed in 1938 was 1,165,015,000 barrels. And that 5 percent of this, as you have just stated, 5 percent is the correct percentage, amounts to 58,251,000 barrels; and the average imports of taxable crude petroleum for the last 5 years were 34,539,000 barrels.

Will you correct these figures if they are not right? I think it is a good place in the record to talk about this a little bit. Are the figures right, Mr. Redfield?

Mr. REDFIELD. Let me take the average, as I have the figures in front of me.

Mr. COLE. In conclusion, the article from which I read, however, is that more than 20,000,000 barrels of oil, therefore, may be imported annually under the Venezuelan agreement at half the old tax, if the Government "generalizes" the reduction, as it undoubtedly will do in line with its most-favored-nation policy.

Mr. REDFIELD. The 5-year average, according to the figures I have in front of me, which refer to continental United States, amounts to 30,800,000. It is possible that the figures cited may have included unfinished oils.

Mr. COLE. I am reading from an article by Mr. Essary, of the Baltimore Sun. He gives 34,539,000.

Mr. REDFIELD. The greatest amount of crude——

Mr. COLE. He says the average for the last 5 years was 34,539,000 barrels; and you say it is 30,000,000?

Mr. REDFIELD. 30,800,000 of crude petroleum, designated as such. These are Bureau of Mines figures that I am quoting, and refer to the continental United States.

Mr. COLE. Well, the Baltimore Sun is very often wrong, but seldom Mr. Essary. [Laughter.]

Mr. REDFIELD. In general, imports of mineral oils into continental United States have increased steadily during the period under review, from January 1, 1934, to August 31, 1939. They totaled 138,000 barrels daily during 1934, and 163,000 barrels daily during the first 8 months of 1939. The increase has been chiefly in imports of fuel oil and of unfinished oils for further processing in American refineries. Imports of crude petroleum have shown a declining trend, from 97,000 barrels daily in 1934 to 72,000 barrels daily in 1938, recovering in the first 8 months of 1939 to 88,000 barrels daily.

In terms of the total national demand for mineral oils, however, the record of imports is not impressive. They constituted 5 percent of the total demand, domestic and foreign, from 1934 to 1936; 4 percent from 1937 to 1938; and 4 percent during the first 8 months of 1939.

From another aspect, imports of mineral oils into continental United States may be divided into two categories: Those intended for direct consumption within the United States, and those intended for consumption on the high seas or for processing and export of the finished products. Imports of mineral oils subject to excise tax for direct consumption in continental United States have been fairly level from January 1, 1934, to August 31, 1939, at no time exceeding the 98,000 barrels daily, which was set as a standard during the operation of the Petroleum Code, although that code became inoperative on May 27, 1935. The general increase in imports noted above has been due to receipts of mineral oils in bond, chiefly in receipts of fuel oil in bond for supplying vessels engaged in foreign trade, in trade between the Atlantic and Pacific coasts of the United States, or between continental United States and the noncontiguous territories. Little advantage has been taken of the provision in the revenue act which exempts from excise taxes oils imported for processing in the United States and export of the finished products.

The importation of mineral oils into the United States is essentially a regional problem. Ninety percent of all oils imported into continental United States have been received through the Atlantic coast ports, and the remaining 10 percent through Gulf coast ports. While the Atlantic Coast States have received 90 percent of the total imports, these have constituted only 12 percent of the oils brought into the Atlantic coast States from outside sources from 1935 to 1938. Shipments by tanker from the Gulf coast constituted the major source of their petroleum supply, amounting to 85 percent of the total.

The mineral oils imported into continental United States are still drawn almost entirely from neighboring countries of Latin America. Imports from Venezuela, chiefly of crude petroleum, have shown a slight downward trend. Imports from the Netherlands West Indies, chiefly of fuel oil, have increased. The decline and almost complete disappearance of imports of high-grade crude petroleum from Colombia may be ascribed largely to the effect of the excise taxes which have tended to favor the importation of heavier crudes for the manufacture of asphalt. Receipts of heavy Mexican crude and Mexican fuel oil from 1934 to 1937 were small and varied little from year to year; after the expropriation of the principal foreign companies operating in Mexico on March 18, 1938, these have been confined chiefly to entries in bond for refining and export, or for supplies of vessels.

In spite of the increase in imports which has been described, the United States is still a net exporter of mineral oils. In fact, net exports and territorial shipments of mineral oils from continental United States have increased from 176,000 barrels daily in 1934 to 382,000 barrels daily in 1938 and 365,000 barrels daily in the first 8 months of 1939. They were equivalent to 7 percent of our total production of crude petroleum in 1934 and to 11 percent in 1938 and the first 8 months of 1939.

Mr. **Mapes**. What do you mean by "net exports"?

Mr. **Redfield**. Total exports and territorial shipments less total imports. Does that answer your question?

Mr. **Mapes**. The exports over and above the imports?

Mr. **Redfield**. That is correct.

Five years ago exports and territorial shipments of mineral oils from continental United States were still under the influence of the world-wide depression. In 1934 they were but little larger than in 1925. Recovery was rapid during the following 4 years. How much of this recovery——

Mr. **Mapes**. How do you account for the increase in exports?

Mr. **Redfield**. My next sentence: How much of this recovery was due to the increasing motorization and mechanization of the world at large and how much to wars and preparations for wars it is difficult to say. The statistics throw no light on that. Certain it is that the outward shipments of mineral oils from continental United States increased uninterruptedly from a daily average of 314,000 barrels in 1934 to a daily average of 528,000 barrels in the first 8 months of 1939.

These exports and territorial shipments accounted for 11 percent of the total demand, domestic and foreign, for mineral oils in continental United States in 1934, for 15 percent in 1938, and for 14 percent in the first 8 months of 1939.

Mr. COLE. What is the percentage of increase in exports? That figure for the last 8 months of 1939 over the other figure you gave is about 80 percent?

Mr. REDFIELD. Offhand, I would say it is about 65 to 68 percent; roughly a two-thirds increase.

Mr. COLE. Increase this year over the export of 1934?

Mr. REDFIELD. No, sir; increase of the daily average for the first 8 months of 1939 over the daily average in 1934.

Mr. COLE. Yes.

Mr. REDFIELD. Roughly, a two-thirds increase. The most marked increase in exports and territorial shipments of mineral oils from continental United States has been in crude petroleum. In fact, these have increased steadily since 1925, with but a single interruption in 1930. Canada, France, and Japan, which accounted for 94 percent of the crude petroleum exported from the United States in 1934, took 81 percent of these exports in 1938, in spite of receipts from rival sources of supply.

Exports and territorial shipments of motor fuel have increased even more proportionally than of crude petroleum from 1934 to 1938, doubling in quantity. Nevertheless they are still below the amounts exported and shipped to the noncontiguous territories from 1928 to 1930. Europe is still the principal foreign market for American motor fuel, taking more than half of our outward shipments in 1938.

The growing use of the Diesel motor for propelling ships, motortrucks, and railroad trains, and for industrial machinery is reflected in the doubling of our exports and territorial shipments of gas oil and distillate fuel oil from 1934 to 1938, and a small increase during the first 8 months of 1939 over the corresponding period of 1938. The United Kingdom and Germany have been among our best customers for this type of fuel.

Exports and territorial shipments of residual fuel oil have shown a smaller but fairly steady increase. Exports of these heavier fuels are widespread; but more goes to North America, South America, and Asia than to Europe.

The growing industrialization and mechanization of all countries and revival from the great depression has caused exports and territorial shipments of lubricating oils to increase from 1934 to 1938, and during the first 8 months of 1939. The principal sales are to Europe and to such countries of expanding industrialization as Canada, Australia, British India, Japan, Brazil, and the Union of South Africa.

It is probable that the export trade of the United States in mineral oils will be important for many years to come. As long as the wells of the United States produce more petroleum than its people and its industries can currently consume, the surplus will flow into the international market. Except for the depression years, the world demand for petroleum products has been increasing. It will probably continue to increase until another world-wide depression paralyzes industry and reduces purchasing power. Against this general increase in demand must be set new discoveries and development of new fields. The last 5 years have seen development of production in Bahrein Island and Saudi Arabia and increased production in Venezuela, Iran, Iraq, and the Netherland East Indies. New pipe lines in Colombia and in Venezuela promise to enlarge the petroleum output of those countries. Prospecting is being conducted in many parts of the world. These oils may be expected to flow largely to Europe, the major consuming area of the world. Unless demand continues to grow at the same rate as in the past, it is probable that these expanding South American and Asiatic fields will supply a greater proportion of the European market and the exports of mineral oils from the United States will gradually decline. This process, however, will take many years.

Mr. MAPES. What do you think we ought to do about our exports of oil?

Mr. REDFIELD. From what standpoint, Mr. Congressman?

Mr. MAPES. Conservation?

Mr. REDFIELD. I do not feel that it is right for us to recommend policy. The Bureau of Mines is a fact-finding agency. Before the question of imports and exports can be answered, the general policy of conservation in the United States must be determined, one way or another.

Mr. MAPES. You have no recommendation to make on that?

Mr. REDFIELD. No, sir; no recommendation.

Mr. MAPES. You said that the increase in our exports went largely to Canada and Japan and one other country; what was the other country?

Mr. REDFIELD. Do you refer to crude petroleum?

Mr. MAPES. Yes.

Mr. REDFIELD. Canada, France, and Japan have always been our leading customers for crude petroleum.

Mr. MAPES. What percentage goes to Japan?

Mr. REDFIELD. I don't have the figures here, but I can make a supplementary statement to the committee, if you wish.

Mr. MAPES. Do you care to make an estimate, a guess?

Mr. REDFIELD. In 1938, a little less than 30 percent of our crude was exported to Japan. I do not have the figures for the first 8 months of 1939.

Mr. MAPES. Was that a greater or smaller percent than Japan had been receiving?

Mr. REDFIELD. It was a greater percent. In 1937, exports of crude petroleum to Japan were less than 25 percent, a little less than 25 percent.

Mr. COLE. Have you furnished us any figures, Mr. Redfield, showing to what extent American operators engaged in foreign production, to what extent we are importing from our own operators, say?

Mr. REDFIELD. I do not have any figures with me, but I should say that nearly all our imports are crude petroleum and fuel oil; the major imports are exported to the United States by a few large companies which have widespread foreign investments in oil fields and refineries, and either consumed by them in their own refineries or sold to other companies which formerly owned foreign-oil production and still use foreign crude to meet their asphalt requirements.

Mr. COLE. Well, I do not know that you have answered my question on that. I am interested in it and, as I recall, back in 1919, or certainly after the World War there was some encouragement, in fact considerable encouragement given to American operators and capital to develop foreign fields. That is true, is it not?

Mr. REDFIELD. It is.

Mr. COLE. And I am wondering to what extent we are importing from those operations, if you can tell us?

Mr. REDFIELD. I would say that the mineral oils coming into the United States come almost entirely from American companies which are operating abroad, except for such imports as are brought in by the principal foreign corporation in the United States, the Royal Dutch Shell group, and for some imports from Mexico.

Mr. COLE. All right, sir. That is all, thank you, Mr. Redfield. You have filed your statement with the reporter, for the record?

Mr. REDFIELD. I did; thank you.

(The report is in full as follows:)

## FOREIGN TRADE OF CONTINENTAL UNITED STATES IN MINERAL OILS

By A. H. REDFIELD

Five years ago I had the honor to appear before this committee with a discussion of the foreign trade of the United States in mineral oils from the beginning of petroleum imports in 1911 to the middle of 1934. To save unnecessary repetition, I propose to begin the present discussion with the year 1934, referring to previous events only so far as appears necessary to explain the developments of the last 5 years. However, to preserve the continuity of the discussion, the principal tables accompanying this report have been carried back to the year 1925. This year marks the end of the earlier phase when imports from Mexico were dominant and the beginning of receipts from Venezuela and the Netherlands West Indies, which are the principal suppliers of petroleum to the United States today. Moreover these earlier figures give an opportunity to compare developments prior to the adoption of the excise taxes in the Revenue Act of 1932 with developments after that period.

Five years ago imports of mineral oils into the United States were subject to an officially prescribed quota, through the Petroleum Code under authority of the National Industrial Recovery Act. The removal of this official regulation of the quantities imported by the decision of the United States Supreme Court in the *Schechter case* left imports of mineral oils subject only to the economic effects of the excise taxes embodied in the Revenue Act of 1932. The results of this change have been unimportant; while the total quantities of foreign oils received in continental United States have increased, the proportion to the total demand, domestic and foreign, has declined.

In conformity with the practice of the Bureau of Mines statistics of imports and exports in the accompanying report refer to continental United States, exclusive of Alaska, Hawaii, Puerto Rico, and the Virgin Islands. Continental United States forms a geographic unit, in which the total production of crude petroleum, the total refining output, and almost the entire consumption occurs. The shipment of oils to the noncontiguous territories involves a transport problem similar to that of exporting to foreign countries.

In general, imports of mineral oils into continental United States have increased steadily during the period under review, from January 1, 1934, to August 31, 1939. They totaled 138,000 barrels daily during 1934; and 163,000 barrels daily during the first 8 months of 1939. The increase has been chiefly in imports of fuel oil—from 35,000 barrels daily in 1934 to 61,000 barrels daily in 1937 and 49,000 barrels daily in the first 8 months of 1939—and of unfinished oils for further processing in American refineries—from 5,000 barrels daily in 1934 to 25,000 barrels daily in the first 8 months of 1939. Imports of crude petroleum have shown a declining trend, from 97,000 barrels daily in 1934 to 72,000 barrels daily in 1938, recovering in the first 8 months of 1939 to 88,000 barrels daily.

In terms of the total national demand for mineral oils, however, the record of imports is not impressive. They constituted 5 percent of the total demand, domestic and foreign, from 1934 to 1936; 4 percent from 1937 to 1938; and 4 percent during the first 8 months of 1939.

*Mineral oils, crude and refined, imported into continental United States, 1925–38*

[In thousands of barrels]

| | Crude petroleum | Fuel oil | Unfinished oils | Gasoline | Lubricating oils | Other | Total |
|---|---|---|---|---|---|---|---|
| 1925 | 61,385 | 12,107 | 210 | 3,698 | 37 | 54 | 77,491 |
| 1926 | 59,920 | 13,981 | 819 | 5,398 | 33 | 95 | 80,246 |
| 1927 | 58,383 | 7,920 | 89 | 4,782 | 7 | 176 | 71,357 |
| 1928 | 79,563 | 7,039 | 16 | 3,914 | 8 | 282 | 90,822 |
| 1929 | 78,922 | 20,319 | 1 | 8,624 | 33 | 340 | 108,239 |
| 1630 | 62,113 | 25,772 | 145 | 16,656 | 18 | 266 | 104,970 |
| 1931 | 47,225 | 24,294 | 37 | 13,379 | 23 | 135 | 85,093 |
| 1932 | 44,682 | 21,286 | 10 | 8,205 | 12 | 299 | 74,494 |
| 1933 | 31,893 | 13,215 | ---------- | 15 | 1 | 270 | 45,394 |
| 1934 | 35,558 | 12,634 | 1,764 | 1 | 2 | 535 | 50,494 |
| 1935 | 32,239 | 16,115 | 3,898 | ---------- | 1 | 382 | 52,635 |
| 1936 | 32,327 | 18,801 | 5,534 | 78 | 4 | 360 | 57,104 |
| 1937 | 27,484 | 22,114 | 7,071 | 144 | 7 | 337 | 57,157 |
| 1938 | 26,412 | 21,085 | 6,380 | 79 | ---------- | 287 | 54,243 |

Sources: Bureau of Foreign and Domestic Commerce and Bureau of Mines.

From another aspect, imports of mineral oils into continental United States may be divided into two categories: Those intended for direct consumption within the United States, and those intended for consumption on the high seas or for processing and export of the finished products. This distinction was created by the excise taxes on imported petroleum embodied in the Revenue Act of 1932. Imports of mineral oils subject to excise tax for direct consumption in continental United States have been fairly level from January 1, 1934, to August 31, 1939, at no time exceeding the 98,000 barrels daily which was set as a standard during the operation of the Petroleum Code, although that code became inoperative on May 27, 1935. The general increase in imports noted above has been due to receipts of mineral oils in bond, which grew from 41,000 barrels daily in 1934 to 68,000 barrels in the first 8 months of 1939. It occurred chiefly in receipts of fuel oil in bond for supplying vessels engaged in foreign trade, in trade between the Atlantic and Pacific coasts of the United States, or between continental United States and the noncontiguous territories. Little advantage has been taken of the provision in the revenue act which exempts from excise taxes oils imported for processing in the United States and export of the finished products. Imports of crude and unfinished oils in bond for processing and export totaled only 22,000 barrels daily in the first 8 months of 1939.

*Daily average imports of petroleum, crude and refined, into continental United States, 1934–38, and January–August 1939, in thousands of barrels*

| | 1934 | 1935 | 1936 | 1937 | 1938 | Jan.–Aug. 1939 |
|---|---|---|---|---|---|---|
| Dutiable: | | | | | | |
| Crude petroleum | 84 | 70 | 81 | 70 | 62 | 75 |
| Fuel oil | 12 | 12 | 5 | 7 | 8 | 3 |
| Unfinished oils | ------ | 11 | 11 | 12 | 12 | 16 |
| Other | 1 | ------ | 1 | 1 | 1 | 1 |
| Total dutiable | 97 | 93 | 98 | 90 | 83 | 95 |
| In bond: | | | | | | |
| Crude petroleum | 13 | 18 | 7 | 5 | 10 | 13 |
| Fuel oil | 23 | 32 | 46 | 54 | 50 | 46 |
| Unfinished oils | 5 | ------ | 4 | 7 | 6 | 9 |
| Other | ------ | 1 | 1 | ------ | ------ | ---------- |
| Total in bond | 41 | 51 | 58 | 66 | 66 | 68 |
| Total, dutiable and in bond: | | | | | | |
| Crude petroleum | 97 | 88 | 88 | 75 | 72 | 88 |
| Fuel oil | 35 | 44 | 51 | 61 | 58 | 49 |
| Unfinished oils | 5 | 11 | 15 | 19 | 18 | 25 |
| Other | 1 | 1 | 2 | 1 | 1 | 1 |
| Grand total | 138 | 144 | 156 | 156 | 149 | 163 |

Sources: Bureau of Foreign and Domestic Commerce; Bureau of Mines.

The importation of mineral oils into the United States is essentially a regional problem. Eighty-seven percent of the mineral oils imported into the United States from 1934 to 1938 entered ports of the Atlantic seaboard. Ten percent were received at Gulf coast ports, and most of the remaining 3 percent in the noncontiguous territories, chiefly Puerto Rico and the Virgin Islands. While the Atlantic Coast States received 87 percent of all oils imported into the United States as a whole, or 90 percent of all oils imported into continental United States, these oils constituted only 12 percent of the oils brought into the Atlantic Coast States from outside sources from 1935 to 1938. Shipments by tanker from the Gulf coast constituted the major source of their petroleum supply, amounting to 85 percent of the total.

In the accompanying table of imports of mineral oils into the United States by regions, the figures have been taken directly from the publications of the Bureau of Foreign and Domestic Commerce, without the adjustments customarily made by the Bureau of Mines. Consequently there are some differences in the classification, notably of fuel oil and unfinished oils, and unimportant differences in the totals for continental United States.

*Mineral oils, crude and refined, imported into the United States, 1934–38, by regions, in thousands of barrels*

| | Crude petroleum | Fuel oil, including topped petroleum | Unfinished oils | Gasoline | Lubricating oil | Other | Total |
|---|---|---|---|---|---|---|---|
| Atlantic coast: | | | | | | | |
| 1934 | 32, 326 | 13, 187 | 311 | 134 | 1 | 179 | 46, 138 |
| 1935 | 26, 254 | 19, 380 | 158 | 8 | 1 | 281 | 46, 082 |
| 1936 | 29, 792 | 20, 020 | 207 | 1 | 2 | 134 | 50, 156 |
| 1937 | 25, 492 | 27, 900 | 105 | -------- | 3 | 493 | 53, 993 |
| 1938 | 23, 826 | 23, 756 | 25 | 5 | 1 | 238 | 47, 851 |
| Gulf coast: | | | | | | | |
| 1934 | 3, 426 | 268 | -------- | -------- | 1 | 11 | 3, 706 |
| 1935 | 6, 076 | 1, 433 | -------- | -------- | -------- | 70 | 7, 579 |
| 1936 | 3, 165 | 1, 655 | 1, 392 | -------- | -------- | 40 | 6, 252 |
| 1937 | 1, 819 | 210 | 2, 565 | 3 | -------- | 31 | 4, 628 |
| 1938 | 2, 300 | 142 | 1, 820 | -------- | -------- | 793 | 5, 055 |
| Other continental United States: | | | | | | | |
| 1934 | -------- | 37 | 11 | 1 | 1 | 13 | 63 |
| 1935 | -------- | 49 | 7 | -------- | 1 | 13 | 70 |
| 1936 | -------- | 265 | 2 | -------- | 3 | -------- | 270 |
| 1937 | -------- | 26 | 102 | -------- | 3 | 109 | 240 |
| 1938 | -------- | 9 | 6 | -------- | 6 | 14 | 35 |
| Noncontiguous territories: | | | | | | | |
| 1934 | 19 | 985 | -------- | -------- | 5 | 4 | 1, 013 |
| 1935 | 14 | 1, 274 | 43 | 1 | 5 | 4 | 1, 341 |
| 1936 | -------- | 1, 718 | 189 | -------- | 5 | -------- | 1, 912 |
| 1937 | -------- | 1, 517 | 252 | 1 | 6 | -------- | 1, 776 |
| 1938 | -------- | 1, 406 | -------- | -------- | 4 | 166 | 1, 576 |
| Total United States: | | | | | | | |
| 1934 | 35, 771 | 14, 477 | 322 | 135 | 8 | 207 | 50, 920 |
| 1935 | 32, 344 | 22, 136 | 208 | 9 | 7 | 368 | 55, 072 |
| 1936 | 32, 957 | 23, 658 | 1, 790 | 1 | 10 | 174 | 58, 590 |
| 1937 | 27, 311 | 29, 653 | 3, 024 | 4 | 12 | 633 | 60, 637 |
| 1938 | 26, 126 | 25, 313 | 1, 851 | 5 | 11 | 1, 211 | 54, 517 |

Source: Bureau of Foreign and Domestic Commerce.

The mineral oils imported into continental United States are still drawn almost entirely from neighboring countries of Latin America. Imports from Venezuela, chiefly of crude petroleum, have shown a slight downward trend. Imports from the Netherland West Indies, chiefly of fuel oil, have increased. The decline and almost complete disappearance of imports of high-grade crude petroleum from Colombia may be ascribed largely to the effect of the excise taxes which have tended to favor the importation of heavier crudes for the manufacture of asphalt. Receipts of heavy Mexican crude and Mexican fuel oil from 1934 to 1937 were small and varied little from year to year; after the expropriation of the principal foreign companies operating in Mexico on March 18, 1938, these have been confined chiefly to entries in bond for refining and export or for supplies of vessels.

*Mineral oils, crude and refined, imported into the United States, 1925–38, by countries of origin, in thousands of barrels*

| | Mexico | Trinidad | Peru | Netherlands West Indies | Venezuela | Colombia | Ecuador | Other | Total [1] |
|---|---|---|---|---|---|---|---|---|---|
| 1925 | 70, 122 | 320 | 1, 825 | 4, 167 | 1. 419 | | | 295 | 78, 148 |
| 1926 | 56, 552 | 792 | 3. 044 | 10. 649 | 5, 285 | 3, 621 | 144 | 1, 197 | 81, 284 |
| 1927 | 34, 174 | 860 | 1, 937 | 14, 202 | 11, 431 | 7, 962 | | 1. 098 | 71, 664 |
| 1928 | 22, 365 | 1, 164 | 1, 276 | 30, 308 | 22, 226 | 11, 838 | 765 | 1, 525 | 91, 467 |
| 1929 | 14. 738 | 1, 234 | 1, 454 | 42, 052 | 34, 496 | 12, 620 | 1, 279 | 692 | 108, 565 |
| 1930 | 12, 001 | 1, 453 | 1, 281 | 49, 226 | 25, 502 | 14, 204 | 1, 215 | 628 | 105, 510 |
| 1931 | 9, 518 | 1, 564 | 225 | 33, 377 | 21, 255 | 12, 329 | 915 | 6, 769 | 85, 952 |
| 1932 | 9, 277 | 1, 248 | 120 | 25, 998 | 25. 693 | 10. 550 | 937 | 1, 105 | 74, 928 |
| 1933 | 6, 590 | 252 | 19 | 12. 651 | 17, 295 | 7, 688 | 857 | 563 | 45, 915 |
| 1934 | 7, 029 | 59 | | 13, 751 | 25, 305 | 4, 339 | 80 | 160 | 50. 723 |
| 1935 | 4, 137 | 58 | | 21, 371 | 24, 597 | 4, 293 | | 258 | 54, 714 |
| 1936 | 7, 247 | 115 | | 20, 721 | 28, 490 | 72 | | 1, 792 | 58, 437 |
| 1937 | 7, 154 | 192 | | 26, 719 | 23, 187 | 431 | | 2, 320 | 60. 003 |
| 1938 | 2. 906 | | | 25, 137 | 23, 567 | | | 1, 171 | 52, 781 |

[1] Exclusive of wax and asphalt.

Source: Bureau of Foreign and Domestic Commerce.

In spite of the increase in imports which has been described, the United States is still a net exporter of mineral oils. In fact, net exports and Territorial shipments of mineral oils from continental United States have increased from 176,000 barrels daily in 1934 to 382,000 barrels daily in 1938 and 365,000 barrels daily in the first 8 months of 1939. They were equivalent to 7 percent of our total production of crude petroleum in 1934 and to 11 percent in 1938 and the first 8 months of 1939.

Five years ago exports and Territorial shipments of mineral oils from continental United States were still under the influence of the world-wide depression. In 1934 they were but little larger than in 1925. Recovery was rapid during the following 4 years. How much of this recovery was due to the increasing motorization and mechanization of the world at large and how much to wars and preparations for wars, it is difficult to say. Certain it is that the outward shipments of mineral oils from continental United States increased uninterruptedly from a daily average of 314,000 barrels in 1934 to a daily average of 528,000 barrels in the first 8 months of 1939.

*Daily average exports and territorial shipments of petroleum, crude and refined, from continental United States, 1934–38 and January–August 1939, in thousands of barrels*

| | 1934 | 1935 | 1936 | 1937 | 1938 | Jan.-Aug. 1939 |
|---|---|---|---|---|---|---|
| Crude petroleum | 113 | 141 | 138 | 184 | 212 | 199 |
| Refined products: | | | | | | |
| Motor fuel | 68 | 84 | 78 | 105 | 138 | 129 |
| Kerosene | 27 | 18 | 19 | 24 | 20 | 22 |
| Gas oil and distillate fuel oil | 40 | 44 | 56 | 83 | 82 | 91 |
| Residual fuel oil | 39 | 35 | 39 | 42 | 48 | 50 |
| Lubricating oil | 21 | 23 | 24 | 30 | 26 | 31 |
| Other | 6 | 8 | 7 | 5 | 5 | 6 |
| Total refined | 201 | 212 | 223 | 289 | 319 | 329 |
| Total crude and refined | 314 | 353 | 361 | 473 | 531 | 528 |
| Total imports | 138 | 144 | 156 | 156 | 149 | 163 |
| Net exports | 176 | 209 | 205 | 317 | 382 | 355 |

Sources: Bureau of Foreign and Domestic Commerce; Bureau of Mines.

Sales to outsiders have increased somewhat in relative importance to the petroleum industry. Exports and territorial shipments accounted for 11 percent of the total demand, domestic and foreign, for mineral oils in continental United States in 1934, for 15 percent in 1938, and for 14 percent in the first 8 months of 1939.

*Mineral oils, crude and refined, exported and shipped to noncontiguous territories from continental United States, 1925–38, in thousands of barrels*

| | Crude petroleum | Motor fuel | Kerosene | Gas oil and distillate fuel oil | Residual fuel oil | Lubricating oil | Other | Total |
|---|---|---|---|---|---|---|---|---|
| 1925 | 13, 337 | 31, 630 | 21, 212 | 36, 088 | | 9, 678 | 1, 820 | 113, 765 |
| 1926 | 15, 406 | 43, 693 | 22, 247 | 38, 351 | | 9, 438 | 2, 731 | 131, 866 |
| 1927 | 15, 844 | 44, 849 | 19, 536 | 47, 391 | | 9, 776 | 3, 941 | 141, 337 |
| 1928 | 18, 965 | 53, 281 | 22, 019 | 44, 427 | | 11, 023 | 5, 099 | 154, 814 |
| 1929 | 26, 401 | 61, 928 | 22, 022 | 39, 151 | | 10, 860 | 2, 616 | 162, 978 |
| 1930 | 23, 705 | 65, 459 | 16, 884 | 36, 450 | | 9, 935 | 3, 939 | 156, 372 |
| 1931 | 25, 546 | 45, 606 | 12, 710 | 29, 224 | | 8, 125 | 3, 183 | 124, 394 |
| 1932 | 27, 393 | 35, 438 | 11, 044 | 8, 782 | 11, 212 | 6, 851 | 2, 555 | 103, 275 |
| 1933 | 36, 584 | 29, 321 | 8, 959 | 11, 424 | 9, 139 | 8, 218 | 3, 082 | 106, 727 |
| 1934 | 41, 127 | 24, 686 | 9, 781 | 14, 506 | 14, 099 | 7, 660 | 2, 648 | 114, 507 |
| 1935 | 51, 430 | 30, 613 | 6, 651 | 16, 249 | 12, 699 | 8, 499 | 2, 846 | 128, 987 |
| 1936 | 50, 313 | 28, 646 | 6, 936 | 20, 448 | 14, 435 | 8, 691 | 2, 705 | 132, 174 |
| 1937 | 67, 234 | 38, 306 | 8, 886 | 30, 129 | 15, 304 | 10, 975 | 1, 983 | 172, 817 |
| 1938 | 77, 273 | 50, 198 | 7, 513 | 29, 903 | 17, 728 | 9, 402 | 1, 706 | 193, 723 |

Sources: Bureau of Foreign and Domestic Commerce; Bureau of Mines.

The most marked increase in exports and Territorial shipments of mineral oils from continental United States has been in crude petroleum. In fact these have increased steadily since 1925, with but a single interruption in 1930. Canada, France, and Japan, which accounted for 94 percent of the crude petroleum exported from the United States in 1934, took 81 percent of these exports in 1938, in spite of receipts from rival sources of supply. Italy, Argentina, Sweden, and Cuba have taken increasing amounts of United States crude. In all the countries mentioned governmental policy has encouraged the construction and operation of refineries, in spite of the lack of an adequate supply of domestic petroleum.

Exports and Territorial shipments of motor fuel have increased even more proportionally than of crude petroleum from 1934 to 1938, doubling in quantity. Nevertheless they are still below the amounts exported and shipped to the noncontiguous territories from 1928 to 1930. Europe is still the principal foreign market for American motor fuel, taking more than half of our outward shipments in 1938, in spite of increased shipments of gasoline to Europe from the Netherlands West Indies, Iran, and the Netherlands East Indies. The causes of these increased sales to Europe must be sought in increasing motorization as well as in wars and preparations for war.

The decline in exports and Territorial shipments of kerosene from continental United States which has been manifested since 1930 has been leveled off in the last 5 years. Nevertheless outward shipments of kerosene from 1934 to 1938 amounted to only 37 percent of those made from 1925 to 1929. Increased use of electricity for lighting in all parts of the world is perhaps the greatest single cause for this decline.

On the contrary, the growing use of the Diesel motor for propelling ships, motortrucks, and railroad trains and for industrial machinery is reflected in the doubling of our exports and Territorial shipments of gas oil and distillate fuel oil from 1934 to 1938, and a small increase during the first 8 months of 1939 over the corresponding period of 1938. The United Kingdom and Germany have been among our best customers for this type of fuel.

Exports and Territorial shipments of residual fuel oil have shown a smaller but fairly steady increase. Exports of these heavier fuels are widespread; but more goes to North America, South America, and Asia than to Europe.

The growing industrialization and mechanization of all countries and revival from the great depression has caused exports and Territorial shipments of lubricating oils to increase from 1934 to 1938 and during the first 8 months of 1939. The principal sales are to Europe and to such countries of expanding industrialization as Canada, Australia, British India, Japan, Brazil, and the Union of South Africa.

It is probable that the export trade of the United States in mineral oils will be important for many years to come. As long as the wells of the United States produce more petroleum than its people and its industries can currently consume, the surplus will flow into the international market. Except for the depression years, the world demand for petroleum products has been increasing. It will probably continue to increase until another world-wide depression paralyzes industry and reduces purchasing power. Against this general increase in demand must be set new discoveries and development of new fields. The last 5 years have seen development of production in Bahrein Island and Saudi Arabia and increased production in Venezuela, Iran, Iraq, and the Netherlands East Indies. New pipe lines in Colombia and in Venezuela promise to enlarge the petroleum output of those countries. Prospecting is being conducted in many parts of the world. These oils may be expected to flow largely to Europe, the major consuming area of the world. Unless demand continues to grow at the same rate as in the past, it is probable that these expanding South American and Asiatic fields will supply a greater proportion of the European market and the exports of mineral oils from the United States will gradually decline. This process, however, will take many years.

*Crude petroleum produced in principal countries of the world, 1934–38, in thousands of barrels*

[Compiled by R. B. Miller]

| Country | 1934 | 1935 | 1936 | 1937 | 1938 [1] |
|---|---|---|---|---|---|
| North America: | | | | | |
| Canada | 1,411 | 1,447 | 1,500 | 2,944 | 6,956 |
| Mexico | 38,172 | 40,241 | 41,028 | 46,907 | 34,794 |
| Trinidad | 10,894 | 11,671 | 13,237 | 15,503 | 17,736 |
| United States | 908,065 | 996,596 | 1,099,687 | 1,279,160 | 1,213,254 |
| Other North America | 28 | 47 | 62 | 33 | 32 |
| Total North America | 958,570 | 1,050,002 | 1,155,514 | 1,344,547 | 1,272,772 |
| South America: | | | | | |
| Argentina | 14,025 | 14,297 | 15,458 | 16,355 | 16,937 |
| Bolivia | 159 | 164 | 105 | 122 | 107 |
| Colombia | 17,341 | 17,598 | 18,756 | 20,298 | 22,450 |
| Ecuador | 1,637 | 1,732 | 1,951 | 2,161 | 2,246 |
| Peru | 16,314 | 17,067 | 17,593 | 17,457 | 15,839 |
| Venezuela | 136,103 | 148,254 | 154,794 | 186,775 | 187,369 |
| Total South America | 185,579 | 199,112 | 208,657 | 243,168 | 244,948 |
| Europe: | | | | | |
| Albania | 10 | 41 | 273 | 619 | 489 |
| Czechoslovakia | 178 | 133 | 127 | 122 | 132 |
| France | 557 | 541 | 503 | 502 | 516 |
| Germany | 2,187 | 2,996 | 3,115 | 3,176 | 4,074 |
| Austria | 28 | 44 | 50 | 221 | 366 |
| Hungary | ----- | ----- | ----- | 16 | 318 |
| Italy | 150 | 119 | 123 | 110 | 101 |
| Poland | 3,913 | 3,812 | 3.788 | 3,716 | 3,763 |
| Rumania | 62,438 | 61,773 | 64,188 | 52,709 | 48,366 |
| U. S. S. R. [2] | 174,986 | 182,386 | 199,055 | 195,155 | 202,290 |
| Other Europe | 3 | 2 | 1 | 1 | 1 |
| Total Europe [2] | 244,450 | 251,847 | 271,223 | 256,347 | 260,416 |
| Asia: | | | | | |
| Bahrein Island | 285 | 1,265 | 4,645 | 7,762 | 8,298 |
| Burma | 7,279 | 7,181 | 7,588 | 7,848 | 7,572 |
| India, British | 1,922 | 2,038 | 1,978 | 2,162 | 1,420 |
| Iran (Persia) | 57,851 | 57,273 | 62,718 | 77,877 | 77,230 |
| Iraq | 7,689 | 27,408 | 30,406 | 31,836 | 32,643 |
| Japan (including Taiwan) | 1,821 | 2,249 | 2,440 | 2,488 | 2,557 |
| Netherland India | 46,529 | 47,171 | 50,025 | 56,724 | 57,481 |
| Sakhalin | 2,798 | 2,545 | 3,212 | 3,656 | [3] 3,900 |
| Sarawak and Brunei | 5,140 | 5,546 | 5,209 | 6,009 | 7,012 |
| Saudi Arabia | ----- | ----- | 20 | 65 | 495 |
| Total Asia [4] | 131,314 | 152,676 | 168,241 | 196,427 | 198,608 |
| Africa: | | | | | |
| Egypt | 1,546 | 1,301 | 1,278 | 1,196 | 1,561 |
| Other Africa | 6 | 4 | 3 | 22 | 27 |
| Total Africa | 1,552 | 1,305 | 1,281 | 1,218 | 1,588 |
| Australia and New Zealand | 5 | 5 | 5 | 4 | 4 |
| Undistributed | 4 | 4 | 4 | 4 | 4 |
| Grand Total | 1,521,474 | 1,654,951 | 1,804,925 | 2,041,715 | 1,978.340 |

[1] Figures for 1938 are preliminary and subject to revision.

[2] Includes fields in Russian Asia other than Sakhalin.

[3] Approximate production.

[4] Exclusive of Union of Soviet Socialist Republics fields in Asia other than Sakhalin, which are included with Union of Soviet Socialist Republics in Europe.

Source: Minerals Yearbook.

Mr. COLE. Mr. Kraemer.

## STATEMENT OF A. J. KRAEMER, SENIOR REFINERY ENGINEER, BUREAU OF MINES

Mr. KRAEMER. My name is A. J. Kraemer, and I am senior refinery engineer with the Bureau of Mines, with headquarters in the Washington office.

I have been with the Bureau of Mines since 1923, with various duties in the field and in the Washington office. Prior to that time, I was with the Standard Oil Co. of Kentucky for 5 years in their manufacturing department, and before the war was for 2 years with the Union Oil Co. of California. I spent a year in the Army, and also 1 scholastic year at Massachusetts Institute of Technology, in graduate study. I obtained my bachelor's degree in industrial chemistry from the University of Kentucky, 1915.

Mr. COLE. Mr. Kraemer, you appeared before us in 1934, did you not?

Mr. KRAEMER. Yes, sir.

Mr. COLE. And, as I understand your work, your report today brings up to date pages 1307 to 1375 of part 2 of our hearings at that time?

Mr. KRAEMER. Yes, sir; that is true, Mr. Cole. In making this report, I have used the former report as an outline. And I wish to say at this point that in preparing this report I was associated with Harold M. Thorne, refinery engineer of the Bureau of Mines at the Petroleum Experiment Station of the Bureau at Laramie, Wyo. That station is conducted in cooperation with the University of Wyoming. Mr. Thorne has been with the Bureau of Mines for about 15 years in the Petroleum Division, and before that had been employed by petroleum refining companies in Oklahoma.

Mr. COLE. Mr. Kraemer, in addition to filing your report for printing in the hearings at this time, do you wish to make any statement relative to that work?

Mr. KRAEMER. I would be glad to make any explanatory statement that the committee considers desirable. On the whole, the report covers about the same ground as the former report. Because the former report is largely unavailable we have repeated the statistics for 1932 and 1933 in regard to refinery operations, so that comparisons can be made directly without the necessity of having recourse to the former report.

That section of the report dealing with the refinery operations in the ten sections into which the Bureau of Mines divides the United States for statistical study, shows a marked increase in the production of certain products, gasoline, kerosene, lubricating oil, and asphalt; and it shows also a movement away from inland locations of refineries toward the coast, and particularly toward the gulf coast. The exception to that statement is the Rocky Mountain area which, although it is a small area in point of volume of production and is obviously an inland area, showed an increase of 70 percent in refinery output in 1938 over 1933. A large part of that increased refinery output probably was due to the increased demand for asphalts for surfacing low cost roads, which have had a remarkable development in the Rocky Mountain area and which now is spreading from that territory. The same thing has been done for years, of course, in California.

Mr. COLE. They are using it all through the national parks.

Mr. KRAEMER. Yes, sir; and in that Rocky Mountain area particularly.

The next section of the report is a description of refining processes, which was written largely by Mr. Thorne, and it endeavors to explain in as simple terms as possible the conventional refining processes, distillation, treatment, and other conventional processes; and then deals briefly with the new processes that have been developed during the past 5 years, and back possibly another 5 years before that, but mainly during the past 5 years.

The next section of the report is a discussion of the technical factors affecting supply of and demand for petroleum products, and is an examination of the statistical evidence as to the distribution of consumption of petroleum products. It seems that the inevitable conclusion from that analysis is that the demand for petroleum products arises from the people of the United States as individuals. The demand is an individual demand rather than a group demand, such as, for example, an industrial demand. It might seem strange that a demand arising from millions of individuals would have any effect on or would have any technologic background, because obviously the average person is not an automotive engineer and neither is he an expert in the design of automatic oil burners, for example. However, the technical factors are involved because of the competition among the suppliers of those materials to improve their products to gain the business of individuals. Therefore the nature of the demand is actually a factor in the technologic influence.

The fifth section of the report is a discussion of alternative fuels, coal, oil shale, and alcohol. Dr. Fieldner, of the Bureau of Mines, as I understand, is to follow me, and he will discuss that aspect of the fuel situation.

Mr. COLE. All right, Mr. Kraemer. I have the report here, which goes in the record at this point.

(The report is in full as follows:)

**Manufacture and Use of Petroleum Products (a review of developments, 1934–38), by A. J. Kraemer and H. M. Thorne, containing a chapter, Gasoline Substitutes from Coal, by A. C. Fieldner, J. D. Davis, and H. H. Storch**

# MANUFACTURE AND USE OF PETROLEUM PRODUCTS

## (A REVIEW OF DEVELOPMENTS, 1934–38)

By A. J. KRAEMER [1] and H. M. THORNE.[2]

### INTRODUCTION

In no equal time interval has technical and scientific advancement in petroleum refining in the United States been as rapid and extensive as during the 5-year period 1934–38. The field of these improvements in technique and knowledge ranges from stabilization of crude petroleum in the field to manufacture of aviation gasoline of 100-octane rating or higher. It can be said that the petroleum industry has reached the stage of development where refining now is a chemical industry, no longer consisting mainly of physical separation of crude

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[2] Refinery Engineer, Bureau of Mines, United States Department of the Interior, Laramie, Wyo.

oil into fractions that are given perfunctory and largely empirical treatment with surfuric acid, caustic soda, and litharge. On the contrary, to an increasing extent modern petroleum refining is the chemical transformation of crude petroleum and other hydrocarbon raw materials into hundreds of products, including many that differ markedly in chemical properties from the parent substance. The condition has not come about suddenly, but is the fruition of two decades of scientific research and engineering development. This evolution can be traced step by step as continuous distillation displaced batch stills, cracking augmented gasoline supply and vacuum distillation, and later, solvent refining improved manufacture of lubricating oils.

If one were to select a single process as most representative of the conversion of petroleum refining from a mechanical procedure into a chemical industry, the choice probably would fall upon polymerization in its various phases. Its development was begun at a time when there were no practicable methods for making useful products from the enormous volumes of gases of two principal types—(1) those evolved in the course of petroleum refining and (2) butane and propane, which had been coming into the hands of the industry in ever-increasing volumes as byproducts of natural-gas production, no quantity outlet being available except as fuel at prices competitive with coal.

Another outstanding aspect of petroleum refining during the 5-year period under review is increased technical competence. Examples are: Improved fuel utilization in refining, more and better instrumental control of operations, larger range of available raw materials (for the manufacture of lubricating oils as an example) and the extremes of temperature and pressure employed with a truly amazing record of safety.

Two unfavorable aspects of this record of achievement may be noted—high capital costs and low return on investment. Rapid technical advancement involves technologic obsolescence; that is, equipment is rendered out of date by the march of progress before it is worn out by use. This requires large capital expenditure that must be amortized in a short time if a project is to be profitable.

The petroleum-refining industry has overcome many of its technical difficulties, or at least has made them less onerous, and although considerable headway has been made against its perennial enemy, corrosion, the latter is still a source of worry and expense to petroleum refiners. Higher temperatures and pressures have afforded new opportunities for corrosion to act, and improved metallurgy has made little net advance in combatting it. Technologic obsolescence and corrosion are the primary causes of high capital costs. The industry has largely financed its capital requirements from earnings; as a result it has enjoyed a good credit rating for any capital it has sought from outside sources, and the financing cost thereof has been low.

As stated above, the second unfavorable factor has been low return on investment. Aside from the influence of high capital costs, profits have been low when measured by the criterion of "value added by manufacture." Thus the benefits of the progress made in the petroleum industry during the past 5 years have been felt mainly by ultimate consumers in improved products at lower prices and by the large number of middlemen who service the products of the industry to the public rather than by the producers.

## THE 1934 REPORT AND REASONS FOR THE PRESENT REPORT

A report on the effect of technologic factors on the supply of and demand for petroleum products was included in the record of hearings of a subcommittee of the Committee on Interstate and Foreign Commerce,[3] published in 1934. In addition to discussion of the specific topic embodied in the title, the report included summaries of the quantities and sources of petroleum raw materials (crude petroleum and natural gasoline) used annually by the petroleum-refining industry and the quantities of various products manufactured from those raw materials in each of the 10 districts into which the United States is divided for statistical study of petroleum refining. The report also presented data on sources of alternative or substitute liquid fuels (oil shale, coal, and alcohol) because of general public interest in what can be done to alleviate a possible shortage of petroleum and not because the quantities of

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[3] Kraemer, A. J., A Report on Effect of Technologic Factors on Supply of and Demand for Petroleum Products: Hearings before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, on H. Res. 441, Petroleum Investigation, pt. 2, pp. 1307–1390.

fuels heretofore made from these sources in the United States have economic importance.

This report endeavors to bring the earlier discussion up to date and to direct attention to changes in sources and character of raw materials and in manufactured products by comparing the data for 1932 and 1933, given in the 1934 report, with corresponding figures for 1937 and 1938.

The changes in technologic procedure in the interval since 1933 are more striking than the changes in yields of products, and major emphasis in the present report is placed on progress in the technique of petroleum refining and in utilization of finished products during the 5-year period 1934–38.

## SCOPE OF REFINERS' PROBLEMS

The concern of the refining branch of the petroleum industry is by no means limited to technical problems dealing with the manufacture of products from raw materials. Technologic developments in oil production that affect the quantity and characteristics of the crude oil delivered to the refinery, changes in the technical requirements of consumers leading to improved or modified specifications for various products, economic circumstances (such as changes in the price structure of crude oil and refined products, and adjustments involving the whole social order and the dependence of the entire consuming public on petroleum products), and many other conditions in either the producing or marketing branches affect and influence directly or indirectly the whole refinery program. Thus it is seen that the refining branch of the industry occupies the midposition between the production of crude oil and the marketing of refined products.

Ultimate consumers are not interested in crude petroleum except the small proportion of the total production that is used directly for fuel or for oiling roads. Their demand is for petroleum products. Virtually every barrel of crude oil brought to the surface of the earth by the producing branch of the industry must pass through one or more petroleum refineries before any commodities useful to consumers are obtained. After petroleum has passed through various refining processes and has been converted into finished products it is dispensed to users by the marketing branch of the industry.

The Bureau of Mines estimates that more than 15,000 distinct entities are engaged in petroleum production. These include individual producers, partnerships, separate corporations, and organizations affiliated with partly or completely integrated companies. The American Petroleum Institute estimates that in 1938 there were 408,000 retail outlets for gasoline in the United States.[4] These two sets of figures suggest why the refining branch of the petroleum industry from its midposition must face many complexities aside from those connected with the manufacturing plant.

Influences extraneous to the industry as well as changing conditions in its producing and marketing branches affect petroleum-refining operations. Circumstances in other industries entirely beyond its purview control its operations. For example, many developments in automobile manufacture and in general automotive transportation directly affect the supply of and demand for petroleum products. The magnitude of industrial activity influences the demand for lubricants, fuels, and other petroleum products. Moreover, the conditions in the petroleum-refining industry are continuously being affected by competition among coal, gas, electricity, and oil to satisfy requirements for heat and light.

This indirect control of demand is by no means peculiar to the petroleum industry. However, it must be considered in studying relationships between the supply of and demand for petroleum and its products.

A decisive characteristic of the demand for individual petroleum products is its variation, both quantitative and qualitative. Seasonal variation exemplifies the first factor and the choice or discrimination of the consumer influences the second.

Although the productive capacity of the petroleum-refining industry in the United States is adequate to supply peak demands currently, other considerations make it expedient to provide facilities for storing excess quantities of manufactured products during periods of decreased demand. If this were not done, the demand for crude oil would be erratic, and the employment of refinery workers would be as seasonal as the demand for products. Formerly the de-

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[4] American Petroleum Institute, Petroleum Facts and Figures: 6th ed., 1939, p. 106.

mand for motor fuel was highly seasonal, but this condition has been changed greatly by improvements in roads and streets and by the general use of passenger vehicles that can be operated with ease and occupied in comfort in inclement weather.

The extreme example of changing technical requirements as to quality is seen in the reversal of opinion regarding the relative desirability of straight-run and "cracked" gasoline. Until a few years ago the profit of petroleum refining depended on the manufacture of straight-run gasoline. While that condition was in effect refiners and marketers were loath to admit that their gasoline contained any cracked constituents. At present most of the straight-run gasoline produced in the United States is blended with cracked gasoline and other materials, so the former distinction between straight-run and cracked gasoline no longer applies to service-station gasoline.

The change in demand from straight-run to cracked gasoline is of interest not only to petroleum refiners who must plan to meet the demand but is even more important to producers of crude petroleum. The effect of the cracking process on the demand for crude petroleum is indicated by the fact that 270,471,000 barrels of cracked gasoline were manufactured in 1938. It would have required 1,281,900,000 barrels of crude oil of the average quality run to stills during that year—more than the total production of crude oil in the United States in 1938—to provide this quantity of straight-run gasoline. This effect of the cracking process upon production of crude oil is difficult to evaluate in specific terms. However, it is evident that a vast amount of petroleum has been saved for future use which otherwise would have been produced rapidly to meet a real demand and without the cracking process conditions in the industry would differ markedly from those now in effect.

On the supply side, the petroleum industry is unlike virtually all others in its ability to vary percentage yields for a wide range of products. Because of the closely related chemical constitution of petroleum hydrocarbons, modern refining equipment can transform one product to another according to requirements. If, for example, the meat-packing industry, after taking two hams from a hog, could make still another ham from remaining less desirable parts of the animal or if part of the wheat crop in some miraculous way could be transformed into corn, these circumstances would be comparable to the ability of the petroleum refiner to make gasoline from petroleum residues, chemicals from refinery gas, and lubricating oil from paraffin wax.

It is true that satisfactory outlets have not yet been developed for the total supply of certain products resulting from petroleum-refining processes, although progress is being made in that direction. Outstanding examples are still gas, petroleum coke, and acid sludge. The fact remains, however, that on the basis of refining operations during the past several years the total annual yield of any refined product, except gasoline and fuel oils (which together utilize more than 85 percent of crude oil run to stills), could be doubled if demand (or price) were high enough. Of course, not all of the yields could be doubled simultaneously.

The well-equipped refiner's principal problem, therefore, is to conduct his operations so as to get the greatest net return per barrel of crude oil. For example, on the basis of information available to him, he must decide whether to make gasoline at the expense of kerosene yield or kerosene at the expense of gasoline and gas-oil yield, and whether he can get a high enough price for a greater yield of lubricating oil to justify the additional expense. His judgment in making these decisions, as well as skill in refining, efficacy of refining equipment, and integrity in making good products, have a large part in determining whether or not he stays in the refining business.

This description of circumstances attending petroleum refining may give the impression that refiners have little to worry them in contrast to the advantages they enjoy in variability in yields of products; however, ability to conduct operations so as to realize a profit is hampered by two circumstances beyond their control.

First, when crude petroleum has been brought to the surface of the earth economic considerations require that, except for necessary working stocks, it be refined at least to the extent of removing the lighter fractions, thus permitting sale of the remainder as fuel. The reasons for this include the cost of storing crude oil (including the speculative risk that the price may go down), the effect of large amounts of stored oil upon the price obtainable for oil currently produced, and the loss in volume and in reduction of price per barrel owing to evaporation.

Natural gasoline also presses for a market as soon as it is manufactured, due partly to the volatility of the product and partly to comparative shortage in storage facilities. The fact that this product competes with refinery gasoline appears to have had a depressing effect upon the prices of refinery gasoline in the past.

The second circumstance that introduces an economic hazard into petroleum refining is the difference in actual cost of the same crude oil to different refiners, arising from geographic locations and other factors. This spread in cost often may overcome the advantages of more efficient equipment and greater skill in refining.

Another disturbing factor, not necessarily peculiar to the petroleum industry, is necessitous selling of crude oil and refined products, which may have an adverse effect upon the price of the entire output of a commodity.

In the 1934 report attention was given to the special relationships of consumers to petroleum products. Channels of consumption of various petroleum products were discussed briefly, with particular emphasis on the effect of technologic factors upon supply of and demand for products for the various kinds of consumer needs.

Bureau of Mines Minerals Yearbook 1935 included a chapter, Uses of Petroleum Fuels,[5] in which available data relating to types of petroleum fuels and their various uses and the fuels that were their competitors for those uses were assembled and discussed. With as much accuracy as the material at hand permitted, numbers of individual consuming units for the various fuels were stated.

In both discussions the fact seemed obvious that individuals rather than industries are the principal consumers of petroleum products—a matter of outstanding importance in considering the petroleum industry. This stands in a complementary relation to the equally important fact that people financially interested in the output of crude petroleum and natural gas include many thousands of individuals who have a royalty interest in producing properties or who receive an annual rental on undrilled acreage.

In a later section of the present report this aspect of the petroleum situation is analyzed in greater detail. For the purposes of these introductory remarks it is sufficient to state that as a whole industries are relatively minor consumers of petroleum products. The combined demand of the millions of individual consumers of petroleum products greatly exceeds the total industrial use of such commodities.

The fact seems obvious that not only the high economic standing of petroleum but its political, social, and technologic importance as well derives from the lifelong need for petroleum products by each individual inhabitant of the United States. By comparison with this pandemic demand the requirements of industry for petroleum products take minor rank.

## SCOPE OF REPORT

The discussion in the following pages deals with those factors of the refining branch of the petroleum industry in the United States to which passing reference has been made in this introduction. To facilitate the discussion this study is divided into five sections. Section I summarizes the quantities of raw material (crude petroleum and natural gasoline) used by refineries in the United States and the sources thereof, as well as the quantities of various crude oils in storage.

Section II is a survey of the manufacturing facilities (number and capacity of refineries and cracking plants) and the quantities of various products made in each of the 10 refinery districts in the United States. Statistical data in sections I and II are based on published statistics of the Bureau of Mines, United States Department of the Interior.

Section III gives brief descriptions of the principal refining processes used in the past and those in use or being developed at present. The treating and finishing processes used to produce the major finished commodities are described.

Section IV is devoted (1) to discussion of various technologic factors that affect the supply of and demand for the principal petroleum products and (2) to tracing their principal channels of consumption. The thesis of this section is that a number of influences, some of them entirely without the petroleum indus-

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[5] Kraemer, A. J., Uses of Petroleum Fuels: Bureau of Mines Minerals Yearbook, 1935, pp. 759–70.

try, have important effects upon the supply of and demand for petroleum products, and thus influence the demand for crude petroleum. The fact is pointed out also that certain technologic factors within the purview of the petroleum industry are by no means immutable and that changes in the relative importance of these influences may have important effects upon future supply and demand. This section of the report shows that almost all petroleum products are used by burning them and that individuals rather than industries are the principal consumers.

Alternative sources of petroleum substitutes (coal, oil shale, and alcohol) are discussed briefly in section V.

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The discussion of gasoline substitutes from coal, in section V, was written especially for this report by A. C. Fieldner, chief, Technologic Branch, and chief engineer, Coal Division, and J. D. Davis and H. H. Storch, of the Coal Division, Bureau of Mines.

## SECTION I. CRUDE PETROLEUM IN THE UNITED STATES

The various oil fields in the United States, considered as a whole, yield crude oils having a wide variety of characteristics. The oils range in volatility and fluidity from some more volatile than gasoline to others almost solid at temperatures as high as 75° F. and so heavy that they will not float on water. No two crude oils are exactly alike. However, for convenience, they can be classified broadly into groups according to production areas. The oils in each major group are similar but generally differ from typical oils in other categories. The basis of the grouping in the United States is largely geographical, with principal producing areas as follows:

Appalachian, Lima-Indiana, Illinois-Indiana, Mid-Continent, Gulf Coast, Rocky Mountain, and California.

TABLE 1.—*Production of crude petroleum by districts and States, 1933 and 1938*

[Thousands of barrels of 42 gallons]

| | 1933 | | 1938 production[2] |
|---|---|---|---|
| | Production | Value at wells [1] | |
| Appalachian: | | | |
| New York | 3, 181 | 5, 960 | 5, 045 |
| Pennsylvania | 12, 624 | 23, 590 | 17, 426 |
| West Virginia | 3, 815 | 5, 860 | 3, 684 |
| Eastern and Southeastern Ohio | 3, 203 | 3, 490 | 2, 715 |
| Kentucky | 4, 608 | 3, 780 | 5, 821 |
| Tennessee | 5 | 3 | 32 |
| Total Appalachian | 27, 436 | 42, 683 | 34, 723 |
| Lima-Indiana: | | | |
| Northwestern Ohio | 1, 032 | 1, 050 | 583 |
| Northeastern Indiana | 14 | 9 | ---------- |
| Michigan | 7, 942 | 7, 150 | 19, 211 |
| Total Lima-Indiana | 8, 988 | 8, 209 | 19, 794 |
| Illinois-Indiana: | | | |
| Southwestern Indiana | 723 | 641 | 969 |
| Illinois | 4, 244 | 3, 690 | 23, 929 |
| Total Illinois-Indiana | 4, 967 | 4, 331 | 24, 898 |
| Midcontinent: | | | |
| Kansas | 41, 976 | 27, 700 | 59, 587 |
| Oklahoma | 182, 251 | 120, 800 | 174, 882 |
| Texas, exclusive of coastal and West Texas | 286, 263 | 160, 500 | 287, 658 |

[1] Thousands of dollars.

[2] Subject to revision.

TABLE 1.—*Production of crude petroleum by districts and States, 1933 and 1938*—Continued

| | 1933 | | 1938 production |
|---|---|---|---|
| | Production | Value at wells | |
| West Texas | 55, 344 | 24, 000 | 72, 653 |
| Southeastern New Mexico | 13, 748 | 6, 170 | 35, 408 |
| Arkansas | 11, 686 | 4, 850 | 18, 077 |
| Northern Louisiana | 9, 862 | 5, 700 | 28, 637 |
| Missouri | [3] 17 | [3] 9 | 24 |
| Total Midcontinent | 601, 147 | 349, 729 | 676, 926 |
| Gulf coast: | | | |
| Texas Gulf Coast | 61, 002 | 40, 500 | 115, 303 |
| Louisiana Gulf Coast | 15, 306 | 9, 580 | 66, 175 |
| Total Gulf coast | 76, 308 | 50, 080 | 181, 478 |
| Rocky Mountain: | | | |
| Montana | 2, 273 | 2, 220 | 4, 907 |
| Wyoming | 11, 227 | 6, 570 | 19, 004 |
| Colorado | 919 | 540 | 1, 412 |
| Northwestern New Mexico | 368 | 320 | 351 |
| Utah and Alaska | 13 | 18 | 12 |
| Total Rocky Mountain | 14, 800 | 9, 668 | 25, 686 |
| California | 172, 010 | 143, 300 | 249, 749 |
| Total United States | 905, 656 | 608, 000 | 1, 213, 254 |
| Total Ohio | 4, 235 | 4, 540 | 3, 298 |
| Total Indiana | 737 | 650 | 969 |
| Total Texas | 402, 609 | 225, 000 | 475, 614 |
| Total Louisiana | 25, 168 | 15, 280 | 94, 812 |
| Total New Mexico | 14, 116 | 6, 490 | 35, 759 |

[3] Includes Mississippi.

NOTE.—Value at wells in 1938 by districts and States not yet available; value at wells in 1938 for total United States, $1,390,000,000.

## "BASE" OF A CRUDE OIL

Crude oils often are classified according to their so-called "base." This form of classification as generally used is rather vague and is based largely upon superficial characteristics. In its study of crude petroleum, the Bureau of Mines faced the necessity of devising a classification of petroleum based upon definite criteria. As might be expected, the original basis of classification devised by Bureau technologists has been modified as additional information was obtained regarding characteristics of petroleum. The present Bureau classification of crude petroleum is based upon three principal classes—"paraffin," "intermediate," and "naphthene" base—and four intervening classes—"paraffin-intermediate," "intermediate-paraffin," "intermediate-naphthene," and "naphthene-intermediate." The names of these seven classes indicate the gradation in characteristics of petroleum throughout the range from paraffinic to naphthenic. The term "asphalt base," used originally to classify the crude oils found in the Gulf coast and California districts, has fallen into disuse because it is not as descriptive of the chemical properties of the oil as "naphthene base." Most of the classes of crude oils described above, except those of paraffin base, may contain asphalt.

Paraffin-base crude oils are found mainly in the Appalachian district, intermediate-base oils in the Mid-Continent district, and naphthene-base oils in the Gulf Coast and California districts. However, examples of the three primary classifications as well as of the four intervening types of oils are found widely scattered throughout the United States.

### APPALACHIAN DISTRICT

*Pennsylvania-Grade crude oil.*—This crude oil comprises the oil produced in New York and West Virginia, all but a small proportion of the production of

Pennsylvania, and approximately one-half of the oil produced in central and eastern Ohio.

"Pennsylvania Grade" is a market classification established by the Pennsylvania Grade Crude Oil Association, Oil City, Pa. This crude oil is valued chiefly for its high content of lubricating-oil constituents and the relative ease with which finished lubricants of good quality can be made. In addition to the lubricant fractions this oil contains a comparatively large proportion of gasoline obtainable by simple distillation (straight-run gasoline). Because of the present emphasis on antiknock rating of gasoline the straight-run gasoline from Pennsylvania-Grade crude oil is no longer in demand, and present practice is either to raise its antiknock rating by "re-forming" or to make naphthas for use as solvents from the main portion of the gasoline fraction.

Superior grades of kerosene and Diesel-engine fuel are made from this crude oil. Relatively large quantities of paraffin wax and a comparatively small proportion of distillate fuel oil are manufactured. Very little heavy or residual fuel oil is made from Pennsylvania-Grade crude oil.

*Other Appalachian crude oils.*—The remainder of the Appalachian district comprises portions of the oil fields of eastern and southeastern Ohio that are not included in the Pennsylvania-Grade classification and the oil fields of Kentucky and Tennessee.

The crude oils of this portion of the Appalachian district in general contain less straight-run gasoline than the Pennsylvania-Grade oil, and its antiknock quality is better. More chemical treatment is required to manufacture lubricating oils from these crude oils than for Pennsylvania-Grade oils, and they contain varying proportions of paraffin wax. Road oils and fuel oils in considerable quantity are made from them.

The oils of Ohio, Kentucky, and Tennessee resemble Mid-Continent oils more closely than they do those of Pennsylvania Grade.

Tables 2 to 7, inclusive, give data for the Appalachian area, including production by States; movements, stocks, prices of crude oil; and wells drilled.

TABLE 2.—*Pennsylvania-grade crude oil produced, 1929–38, by States*

[Thousands of barrels of 42 gallons]

| Year | New York | Pennsylvania | West Virginia | Central and Eastern Ohio | Total |
|---|---|---|---|---|---|
| 1929 [1] | 3,377 | 11,820 | 5,574 | 2,654 | 23,425 |
| 1930 | 3,647 | 12,786 | 5,068 | 2,742 | 24,243 |
| 1931 | 3,363 | 11,876 | 4,470 | 2,184 | 21,893 |
| 1932 | 3,508 | 12,396 | 3,875 | 1,741 | 21,520 |
| 1933 | 3,181 | 12,607 | 3,815 | 1,594 | 21,197 |
| 1934 | 3.804 | 14,462 | 4,095 | 1,597 | 23,958 |
| 1935 | 4,236 | 15,794 | 3.901 | 1,547 | 25,478 |
| 1936 | 4,663 | 17,053 | 3,846 | 1,510 | 27,072 |
| 1937 | 5,478 | 19,173 | 3,844 | 1,367 | 29.862 |
| 1938 [2] | 5,045 | 17,408 | 3,684 | 1,179 | 27,316 |

[1] Pennsylvania Grade Crude Oil Association, 1929.
[2] Subject to revision.

TABLE 3.—*Production of crude petroleum in the Appalachian district, 1929–38*

[Thousands of barrels of 42 gallons]

| Year | New York | Pennsylvania | West Virginia | Central and Eastern Ohio | Kentucky | Tennessee | Total |
|---|---|---|---|---|---|---|---|
| 1929 | 3,377 | 11,820 | 5,574 | 5,259 | 7,775 | 19 | 33,824 |
| 1930 | 3,647 | 12,803 | 5,071 | 5,174 | 7,389 | 21 | 34,105 |
| 1931 | 3,363 | 11,892 | 4,472 | 4,212 | 6,456 | 6 | 30,401 |
| 1932 | 3,508 | 12,412 | 3,876 | 3,579 | 6,287 | 5 | 29,667 |
| 1933 | 3,181 | 12,624 | 3,815 | 3,203 | 4,608 | 5 | 27,436 |
| 1934 | 3,804 | 14,478 | 4,095 | 3,258 | 4,860 | 10 | 30,505 |
| 1935 | 4,236 | 15,810 | 3,902 | 3,163 | 5,258 | 15 | 32,384 |
| 1936 | 4,663 | 17,070 | 3,847 | 3,089 | 5,633 | 20 | 34,322 |
| 1937 | 5,478 | 19,189 | 3,845 | 2,933 | 5,484 | 35 | 36,964 |
| 1938 [1] | 5,045 | 17,426 | 3,684 | 2,715 | 5,821 | 32 | 34,723 |

[1] Subject to revision.

### TABLE 4.—*Indicated demand for crude petroleum in the Appalachian district for 1938*

[Thousands of barrels of 42 gallons]

| Source | Total, 1938 | Daily average |
|---|---|---|
| Pennsylvania-Grade area | 26, 695 | 73 |
| Other Appalachian areas, including Kentucky | 7, 278 | 20 |
| Total Appalachian | 33, 973 | 93 |

### TABLE 5.—*Stocks of crude petroleum December 31, 1938 by areas of origin*

[Thousands of barrels of 42 gallons]

| Area of origin | Stocks at refineries | Pipe-line and tank-farm stocks | Total stocks |
|---|---|---|---|
| Pennsylvania-Grade area | 765 | 4, 678 | 5, 443 |
| Other Appalachian areas, including Kentucky | 496 | 726 | 1, 222 |
| Total Appalachian | 1, 261 | 5, 404 | 6, 665 |

### TABLE 6.—*Value of crude petroleum at the wells, 1933–37, in the Appalachian district, by States*

[Total in thousands of dollars; averages in dollars per barrel]

| State | 1933 | | 1934 | | 1935 | | 1936 | | 1937 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Average | Total | Average | Total | Average | Total | Average | Total | Average |
| New York | 5, 960 | 1. 87 | 9, 340 | 2. 46 | 9, 080 | 2. 14 | 11, 380 | 2. 44 | 14, 140 | 2. 58 |
| Pennsylvania | 23, 590 | 1. 87 | 35, 200 | 2. 43 | 33, 840 | 2. 14 | 41, 450 | 2. 43 | 49, 300 | 2. 57 |
| West Virginia | 5, 860 | 1. 54 | 8, 600 | 2. 10 | 7, 220 | 1. 85 | 8, 200 | 2. 13 | 8, 800 | 2. 29 |
| Central and eastern Ohio | 3, 490 | 1. 09 | 5, 550 | 1. 70 | 4, 855 | 1. 53 | 5, 160 | 1. 67 | 5, 060 | 1. 73 |
| Kentucky | 3, 780 | . 82 | 5, 640 | 1. 16 | 6, 000 | 1. 14 | 7, 240 | 1. 29 | 7, 680 | 1. 40 |
| Tennessee | 3 | . 60 | 10 | 1. 00 | 15 | ------ | 18 | . 90 | 35 | 1. 00 |
| Total Appalachian | 42, 683 | 1. 56 | 64, 340 | 2. 11 | 61, 010 | 1. 88 | 73, 448 | 2. 14 | 85, 015 | 2. 30 |

### TABLE 7.—*Oil and gas wells in 1937–38 in the Appalachian district*

| State | Producing oil wells | | Wells drilled, 1938 | | | | |
|---|---|---|---|---|---|---|---|
| | Approximate number Dec. 31, 1937 | Average production per well per day (barrels) | Oil | Gas | Dry | Total | Estimated average daily initial production per well (barrels) |
| New York | 19, 900 | 0. 8 | } 2, 378 | 166 | 95 | 2, 639 | 4 |
| Pennsylvania | 82, 800 | . 6 | | | | | |
| Ohio | 28, 500 | . 3 | 189 | 433 | 288 | 910 | 23 |
| West Virginia | 18, 400 | . 6 | 114 | 484 | 126 | 724 | 13 |
| Kentucky | 13, 700 | 1. 1 | 484 | 91 | 314 | 889 | 89 |
| Total | 163, 300 | . 6 | 3, 165 | 1, 174 | 823 | 5, 162 | 18. 4 |

Table 2 gives the quantity of Pennsylvania-Grade crude oil produced during each of the past 10 years.

Table 3 shows the total output of crude petroleum in the Appalachian district, which includes the oil from the area producing Pennsylvania-Grade crude oil and in addition the quantities of oil that are not of this grade.

The daily average of indicated demand shown in table 4 together with the total stocks given in table 5 indicate that the volume of Pennsylvania-Grade crude oil in storage on December 31, 1938, was equal to 75 days' requirements and that of other Appalachian oil, 61 days' requirements.

Table 6 lists the monetary value of oil produced in the Appalachian district during the years 1933 to 1937, inclusive; this was distributed among many persons, including landowners, holders of royalty interests, wage earners, suppliers of materials for well drilling and maintenance, and many others concerned with oil operations in the Appalachian district. Values for 1938 are not yet available. Although the Appalachian district is made up of old producing fields with individual wells averaging less than 1 barrel per day the total production and value of petroleum in the district have continued to increase through 1937. In that year the value of crude petroleum at the wells was $85,015,000, virtually twice the figure for 1933.

Although the initial production of the completed wells was small, table 7 shows that of the 2,639 wells drilled in New York and Pennsylvania in 1938 only 95 (3.6 percent) were failures. Wells drilled in the other States of the Appalachian region had a higher average initial production but a much greater ratio of dry holes to commercial producers.

## LIMA-INDIANA DISTRICT

This district includes the oil fields of northwestern Ohio, northeastern Indiana, and Michigan. The major portion of the production in this district now comes from Michigan. Drilling for oil was begun in the Lima (Ohio) field in 1885, and many of the wells have been abandoned because they are no longer commercially profitable. Of the remaining wells, the production per well is exceedingly small.

Oil from this district contains more sulfur and asphalt than that from the Appalachian district, and refining is more difficult. However, the oil is a useful stock for manufacture of gasoline, fuel oils, road oils, and asphalt.

Special processes were developed to refine the oil produced in the Lima (Ohio) field. These processes were directed primarily toward elimination of the relatively large amounts of sulfur compounds in the oil, which had not been found in the earlier period when most of the oil refined was from the Appalachian area.

Petroleum produced in Michigan also has presented difficult problems for refiners including, for example, the low octane value of its straight-run gasoline and the persistence of the odor in some other fractions. Processes and equipment especially adapted to the peculiarities of this oil have been necessary for successful manufacture of marketable products. Tables 8 and 10 to 13 give data on the quantity, movements, stocks, and prices of crude oil produced in the Lima-Indiana district, the number of producing wells in December 31, 1937, and the number of wells drilled in 1938, with their average initial production.

## ILLINOIS-INDIANA DISTRICT

This district comprises the oil fields of Illinois and southwestern Indiana. Crude oil from the older fields of this district is similar to that from the older fields of the Lima-Indiana district, but the crude oil from the new Illinois fields is similar to the better grades of Mid-Continent oils. The Illinois-Indiana district has been producing since about 1899–1900; and the output from individual wells, like that of the Lima-Indiana district, is small, except from wells in the more recently discovered fields of south-central Illinois. Changes in refinery demands and availability of "flush" production from other fields has reduced the demand for oil from the older fields, and producers have had difficulty in disposing of their current output, small as it is.

Production from the newer fields of south-central Illinois has increased rapidly since 1937 until it now far overshadows that from the older fields of eastern Illinois and southwestern Indiana. Illinois production increased from about 4.5 million barrels in 1936 to almost 24 million barrels in 1938 due to the additional production from the new fields.

Tables 9 to 13, inclusive, give data on production, movements, stocks, and prices of crude oil and wells drilled in the Illinois-Indiana districts.

TABLE 8.—*Production of crude petroleum in the Lima-Indiana district, 1929–38*

[Thousands of barrels of 42 gallons]

| Year | North-western Ohio | North-eastern Indiana | Michigan | Total |
|---|---|---|---|---|
| 1929 | 1, 484 | 63 | 4, 528 | 6, 075 |
| 1930 | 1, 312 | 53 | 3, 911 | 5, 276 |
| 1931 | 1, 115 | 37 | 3, 789 | 4, 941 |
| 1932 | 1, 065 | 29 | 6, 910 | 8, 004 |
| 1933 | 1, 032 | 14 | 7, 942 | 8, 988 |
| 1934 | 976 | 24 | 10, 603 | 11, 603 |
| 1935 | 919 | 20 | 15, 776 | 16, 715 |
| 1936 | 758 | 20 | 11, 928 | 12, 706 |
| 1937 | 626 | 18 | 16, 628 | 17, 272 |
| 1938 [1] | 583 | ------------ | 19, 211 | 19, 794 |

[1] Subject to revision.

TABLE 9.—*Production of crude petroleum in the Illinois-Indiana district, 1929–38*

[Thousands of barrels of 42 gallons]

| Year | Illinois | South-western Indiana | Total | Year | Illinois | South-western Indiana | Total |
|---|---|---|---|---|---|---|---|
| 1929 | 6, 319 | 918 | 7, 237 | 1934 | 4, 479 | 814 | 5, 293 |
| 1930 | 5, 736 | 941 | 6, 677 | 1935 | 4, 322 | 757 | 5, 079 |
| 1931 | 5, 039 | 803 | 5, 842 | 1936 | 4, 475 | 802 | 5, 277 |
| 1932 | 4, 673 | 777 | 5, 450 | 1937 | 7, 499 | 826 | 8, 325 |
| 1933 | 4, 244 | 723 | 4, 967 | 1938 [1] | 23, 929 | 969 | 24, 898 |

[1] Subject to revision.

TABLE 10.—*Indicated demand for crude petroleum in the Lima-Indiana and Illinois-Indiana districts for 1938*

[Thousands of barrels of 42 gallons]

| Source | 1938 | Daily average |
|---|---|---|
| Lima-Northeastern Indiana-Michigan | 19, 766 | 54 |
| Illinois-Southwestern Indiana | 23, 408 | 64 |
| Total | 43, 174 | 108 |

TABLE 11.—*Stocks of crude petroleum, Dec. 31, 1938, by areas of origin*[1]

[Thousands of barrels of 42 gallons]

| Area of origin | Stocks at refineries | Pipe-line and tank-farm stocks | Total stocks |
|---|---|---|---|
| Lima-Indiana-Michigan | 515 | 880 | 1, 395 |
| Illinois-Indiana | 659 | 10, 484 | 11, 143 |
| Total | 1, 174 | 11, 364 | 12, 538 |

[1] Subject to revision.

TABLE 12.—*Value of crude petroleum at the wells, 1933–37, in the Lima-Indiana and Illinois-Indiana districts, by areas*

[Totals in thousands of dollars; averages in dollars per barrel]

| | 1933 | | 1934 | | 1935 | | 1936 | | 1937 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Average | Total | Average | Total | Average | Total | Average | Total | Average |
| Northwestern Ohio | 1,050 | $1.02 | 1,280 | $1.31 | 1,065 | $1.16 | 930 | $1.23 | 760 | $1.21 |
| Northeastern Indiana | 9 | .64 | 30 | 1.25 | 25 | 1.25 | 25 | 1.25 | 25 | 1.39 |
| Michigan | 7,150 | .90 | 10,820 | 1.02 | 16,350 | 1.04 | 15,950 | 1.34 | 21,950 | 1.32 |
| Total Lima-Indiana | 8,209 | .91 | 12,130 | 1.05 | 17,440 | 1.05 | 16,905 | 1.33 | 22,735 | 1.32 |
| Illinois | 3,690 | .87 | 4,990 | 1.11 | 4,810 | 1.11 | 5,390 | 1.20 | 9,970 | 1.33 |
| Southwestern Indiana | 641 | .89 | 930 | 1.14 | 855 | 1.13 | 985 | 1.23 | 7,115 | 1.35 |
| Total Illinois-Indiana | 4,331 | .87 | 5,920 | 1.12 | 5,665 | 1.12 | 6,375 | 1.21 | 16,085 | 1.33 |

TABLE 13.—*Oil and gas wells in 1937–38, Lima-Indiana and Illinois-Indiana districts*

| State | Producing oil wells | | Wells drilled in 1938 | | | | Estimated average daily initial production per well |
|---|---|---|---|---|---|---|---|
| | Approximate number Dec. 31, 1937 | Average production per well per day | Oil | Gas | Dry | Total | |
| Northwestern Ohio | 9,800 | 0.2 | (1) | (1) | (1) | (1) | (1) |
| Northeastern Indiana | 100 | .5 | (2) | (2) | (2) | (2) | (2) |
| Michigan | 1,780 | 29.0 | 566 | 28 | 406 | 1,000 | 451 |
| Total Lima-Indiana | 11,680 | | | | | | |
| Illinois | 14,110 | 1.5 | 1,806 | 23 | 408 | 2,237 | 271 |
| Southwestern Indiana | 1,140 | 2.0 | 46 | 43 | 69 | 159 | 37 |
| Total Illinois-Indiana | 15,250 | | | | | | |

[1] Included in table 7.
[2] Included in Southwestern Indiana.

Table 8 indicates that the major portion of the production in the Lima-Indiana district during the past 10 years has come from the Michigan fields. Production in northwestern Ohio in 1938 was about one-third of what it was in 1929, and has virtually ceased in northeastern Indiana.

Table 9 shows that production in Illinois decreased from 1929 to 1933, increased slightly in 1934 and 1936, almost doubled in 1937, and increased in 1938 to more than five times the output in 1935. The increases in 1937 and 1938 were due to discoveries of new fields. Southwestern Indiana showed little change in production over the 10-year period.

The data in tables 10 and 11 reveal that the stocks of petroleum obtained from fields of the Lima-Indiana district constitute 26 days' supply, based upon the daily average rate of demand in 1938, whereas stocks of petroleum accumulated from fields of the Illinois-Indiana district constitute 174 days' supply.

Table 12 shows that the total value of crude oils at the wells for both the Lima-Indiana and Illinois-Indiana districts increased appreciably over the period 1933–37, owing principally to increased production in Michigan and Illinois.

Table 13 proves that Michigan still has considerable drilling activity and that Illinois, ranking second only to Texas in the number of wells completed in 1938, is undergoing an active drilling campaign owing to the discovery of new oil-producing areas.

## MID-CONTINENT DISTRICT

The Mid-Continent district comprises the oil fields of Oklahoma, Arkansas, Kansas, northern Louisiana, southeastern New Mexico, and all of Texas except the Gulf Coast fields. This district contains the famous East Texas field, still by far the largest oil-producing field in the United States. The Mid-Continent is the most important oil-producing district in the United States. In 1938, 676,926,000 barrels of petroleum (55.8 percent of the quantity produced in the United States) was produced in this district.

Crude oils produced in this district as a whole are intermediate in characteristics between Pennsylvania-Grade oils and certain naphthenic oils found in the Gulf Coast district and in California whose fractions have high specific gravity in relation to boiling point and do not contain paraffin wax. Most Mid-Continent crude oils are wax-bearing, and many contain small or large proportions of asphalt. On the whole they are intermediate also in sulfur content between Pennsylvania-Grade and naphthene-base oils. Tables 14 to 18, inclusive, give statistics on production, movements, stocks, prices of crude oils, and wells drilled in the district.

TABLE 14.—*Production of crude petroleum in the Mid-Continent district, 1929–38*

| Year | Northern Louisiana | Arkansas | Kansas | Oklahoma | Texas, except Gulf coast | Southeastern New Mexico | Missouri | Total |
|---|---|---|---|---|---|---|---|---|
| 1929 | 13, 100 | 24, 917 | 42, 813 | 255, 004 | 247, 224 | 1, 222 | ---------- | 584, 280 |
| 1930 | 14, 662 | 19, 702 | 41, 638 | 216, 486 | 229, 391 | 9, 568 | ---------- | 531, 447 |
| 1931 | 12, 244 | 14, 791 | 37, 018 | 180, 574 | 284, 405 | 14, 704 | ---------- | 543, 736 |
| 1932 | 10, 191 | 12, 051 | 34, 848 | 153, 244 | 270, 628 | 12, 062 | [1] 10 | 493, 034 |
| 1933 | 9, 862 | 11, 686 | 41, 976 | 182, 251 | 341, 607 | 13, 748 | [1] 17 | 601, 147 |
| 1934 | 9, 075 | 11, 182 | 46, 482 | 180, 107 | 321, 361 | 16, 488 | [1] 37 | 584, 732 |
| 1935 | 9, 554 | 11, 008 | 54, 843 | 185, 288 | 327, 752 | 20, 113 | [1] 47 | 608, 605 |
| 1936 | 26, 917 | 10, 469 | 58, 317 | 206, 555 | 340, 423 | 26, 817 | 40 | 669, 538 |
| 1937 | 28, 883 | 11, 764 | 70, 761 | 228, 839 | 395, 616 | 38, 466 | 40 | 774, 369 |
| 1938 [2] | 28, 637 | 18, 077 | 59, 587 | 174, 882 | 360, 311 | 35, 408 | 24 | 676, 926 |

[1] Includes Mississippi.
[2] Subject to revision.

TABLE 15.—*Indicated demand for crude petroleum in the Mid-Continent district, 1938*

[Thousands of barrels of 42 gallons]

| Source | 1938 | Daily average |
|---|---|---|
| Northern Louisiana and Arkansas | 46, 714 | 128 |
| West Texas-Southeastern New Mexico | 108, 061 | 296 |
| East Texas | 152, 143 | 417 |
| Other (Oklahoma, Kansas, North Texas, etc.) | 370, 008 | 1, 014 |
| Total Mid-Continent | 676, 926 | 1, 855 |

TABLE 16.—*Stocks of crude petroleum Dec. 31, 1938, by areas of origin*[1]

[Thousands of barrels of 42 gallons]

| Area of origin | Stocks at refineries | Pipe-line and tank-farm stocks | Total stocks |
|---|---|---|---|
| Northern Louisiana and Arkansas | 2, 244 | 5, 521 | 7, 765 |
| West Texas and Southeastern New Mexico | 3, 800 | 19, 757 | 23, 557 |
| Oklahoma, Kansas, North and East Texas, etc | 17, 191 | 109, 619 | 126, 810 |
| Total Mid-Continent | 23, 235 | 134, 897 | 158, 132 |

[1] Subject to revision.

TABLE 17.—*Value of crude petroleum at the wells, 1933–37, in the Mid-Continent district*

[Total in thousands of dollars; averages in dollars per barrel]

| State | 1933 |  | 1934 |  | 1935 |  |
|---|---|---|---|---|---|---|
|  | Total | Average | Total | Average | Total | Average |
| Arkansas | 4, 850 | $0. 42 | 8, 000 | $0. 72 | 7, 930 | $0. 72 |
| Kansas | 27, 700 | . 66 | 47, 850 | 1. 03 | 56, 750 | 1. 03 |
| Northern Lousiana | 5, 700 | . 58 | 8, 450 | . 93 | 8, 990 | . 94 |
| Oklahoma | 120, 800 | . 66 | 183, 700 | 1. 02 | 189, 000 | 1. 02 |
| Southeastern New Mexico | 6, 170 | . 45 | 12, 300 | . 75 | [1] 16, 060 | [1] . 78 |
| West Texas | 24, 000 | . 43 | 38, 450 | . 76 | 42, 200 | . 76 |
| East Texas | 115, 500 | . 56 | 181, 000 | 1. 00 | 176, 200 | 1. 00 |
| Remainder of Texas except Gulf Coast | 45, 000 | . 55 | 81, 500 | . 91 | 81, 420 | . 88 |
| Missouri [2] | 9 | . 53 | 31 | . 54 | 41 | . 72 |
| Total Mid-Continent | 349, 729 |  | 561, 281 |  | 581, 591 |  |

| State | 1936 |  | 1937 |  |
|---|---|---|---|---|
|  | Total | Average | Total | Average |
| Arkansas | 8, 160 | $0. 78 | 11, 400 | $0. 97 |
| Kansas | 65, 900 | 1. 13 | 88, 100 | 1. 25 |
| Northern Lousiana | 28, 900 | 1. 07 | 34, 500 | 1. 19 |
| New Mexico [1] | 22, 930 | . 84 | 36, 600 | . 94 |
| Oklahoma | 232, 100 | 1. 12 | 283, 500 | 1. 24 |
| West Texas | 52, 300 | . 84 | 71, 800 | . 95 |
| East Texas | 190, 900 | 1. 14 | 223, 700 | 1. 31 |
| Remainder of Texas except Gulf Coast | 107, 800 | . 97 | 159, 400 | 1. 07 |
| Missouri | 35 | . 88 | 42 | 1. 05 |
| Total Mid-Continent | 709, 025 |  | 909, 042 |  |

[1] Entire State. [2] Includes Mississippi, 1933–35.

TABLE 18.—*Oil and gas wells in 1937–38, in the Mid-Continent district*

| State | Producing oil wells |  | Wells drilled in 1938 |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  | Approximate number Dec. 31, 1937 | Average production per well per day | Oil | Gas | Dry | Total | Estimated average daily initial production per well |
| Arkansas | 2, 670 | 12. 1 | 204 | 3 | 41 | 251 | 683 |
| Kansas | 21, 850 | 9. 3 | 1, 108 | 200 | 402 | 1, 710 | 581 |
| Northern Louisiana | 3, 050 | 26. 7 | 361 | 116 | 145 | 622 | 465 |
| Oklahoma | 55, 900 | 11. 3 | 986 | 160 | 545 | 1, 691 | 218 |
| East Texas | 24, 100 | 20. 6 | 1, 599 | 1 | 45 | 1, 645 | 1, 282 |
| West Texas | 7, 670 | 32. 2 | 1, 788 | 16 | 241 | 2, 045 | 877 |
| Rest of Texas except Gulf Coast | 38, 950 | 11. 1 | 4, 399 | 288 | 2, 022 | 6, 709 | 319 |
| New Mexico [1] | 1, 920 | 67. 2 | 494 | 19 | 67 | 580 | 370 |
| Missouri | 70 | 1. 3 |  | [2] 3 | [2] 23 | [2] 26 |  |
| Total Mid-Continent | 156, 180 | 14. 4 | 10, 939 | 806 | 3, 531 | 15, 279 | 582 |

[1] Includes entire State. [2] Mississippi.

Table 14 traces the rise and decline in oil production in the various States or sections of States comprising the Mid-Continent district. All these areas, except Arkansas and Texas, showed a decline in production in 1938 compared with 1937. General lowering of demand in this region was the underlying factor for decreased production in most of these States.

Tables 15 and 16 indicate that the volume of Mid-Continent crude petroleum in storage on December 31, 1938, equalled 85 days' requirements based upon indicated demand for 1938.

Tables 17 and 18 show that, although the production in the Mid-Continent district in 1937 was only about 30 percent greater than in 1933, the value at the wells in 1937 was about 2.6 times that of 1933 owing to increased price per barrel.

The sum of the separate items in table 17 showing value of oil at wells in Texas in 1937, plus the value of oil produced in the Texas Gulf Coast area in 1937 (table 21), indicates a value of $594,500,000 for the crude oil produced in Texas in 1937, an average of more than $1,600,000 per day.

### GULF COAST DISTRICT

Gulf Coast petroleums usually are considered naphthene-base oils and often are referred to as asphalt-base oils. However, classification from analytical data indicates that both designations frequently are inapplicable. Although most of the oils are classed as naphthene base intermediate characteristics are ascribed to many of them, and a few have paraffinic characteristics aside from the presence of paraffin wax. The low carbon residue of residuum of many of the oils indicates that they contain little asphalt. This is indicated also by the color, which is green or brown rather than black, and by the low sulfur content, which appears to be incompatible with the presence of more than small proportions of asphalt.

The large number of oil fields, coupled with the fact that many of them have two to eight producing horizons, complicates discussion of Gulf Coast crude oils in a brief review. Practical experience in processing has shown that because of the differences in physical and chemical properties the oil from each field and each stratum presents a separate problem in commercial utilization. Almost every important product of petroleum is made in the large refineries of this district, although some of them are derived from crude oils coming from other areas.

Tables 19 to 22, inclusive, give data on production, movements, stocks, and prices of crude oils and wells drilled in the Gulf Coast district.

TABLE 19.—*Production of crude petroleum in the Gulf Coast district, 1929–38*

[Thousands of barrels of 42 gallons]

| Year | Louisiana Gulf Coast | Texas Gulf Coast | Total |
|---|---|---|---|
| 1929 | 7, 454 | 49, 652 | 57, 106 |
| 1930 | 8, 610 | 61, 066 | 69, 676 |
| 1931 | 9, 560 | 48, 032 | 57, 592 |
| 1932 | 11, 616 | 41, 850 | 53, 466 |
| 1933 | 15, 306 | 61, 002 | 76, 308 |
| 1934 | 23, 794 | 60, 155 | 83, 949 |
| 1935 | 40, 776 | 64, 914 | 105, 690 |
| 1936 | 53, 574 | 86. 988 | 140, 562 |
| 1937 | 62, 041 | 114, 702 | 176, 743 |
| 1938 [1] | 66, 175 | 115, 303 | 181, 478 |

[1] Subject to revision.

TABLE 20. *Stocks of Gulf Coast crude petroleum, December 31, 1938* [1]

[Thousands of barrels of 42 gallons]

| | |
|---|---|
| Stocks at refineries | 10, 000 |
| Pipe-line and tank-farm stocks | 17, 776 |
| Total stocks | 27, 776 |

[1] Subject to revision

TABLE 21.—*Value of crude petroleum at the wells, 1933–37, in the Gulf Coast district*

[Totals in thousands of dollars; averages in dollars per barrel]

| Year | Louisiana Gulf Coast | | Texas Gulf Coast | |
|---|---|---|---|---|
| | Total | Average | Total | Average |
| 1933 | 9, 580 | $0. 63 | 40, 500 | $0. 66 |
| 1934 | 23, 400 | . 98 | 60, 600 | 1. 01 |
| 1935 | 40, 830 | 1. 00 | 65, 000 | 1. 00 |
| 1936 | 56, 700 | 1. 06 | 98, 400 | 1. 13 |
| 1937 | 75, 800 | 1. 22 | 139, 600 | 1. 22 |

TABLE 22.—*Oil and gas wells in 1937–38, in the Gulf Coast district*

| State | Producing oil wells | | Wells drilled in 1938 | | | | Estimated average daily initial production per well |
|---|---|---|---|---|---|---|---|
| | Approximate number Dec. 31, 1937 | Average production per well per day | Oil | Gas | Dry | Total | |
| Louisiana Gulf Coast | 1,110 | 167.5 | 329 | 10 | 186 | 525 | 388 |
| Texas Gulf Coast | 6,640 | 51.8 | 1,106 | 36 | 269 | 1,411 | 425 |
| Total Gulf Coast | 7,750 | 68.4 | 1,435 | 46 | 455 | 1,936 | 417 |

The Gulf Coast district of Louisiana and Texas has made the greatest volume increase in production within the past 10 years of any in the United States. Table 19 shows that production in the district increased threefold during this period. The greatest volume increase occurred in the Texas Gulf Coast, but the greatest percentage increase was in the Louisiana Gulf Coast area.

Table 21 shows that the value of the crude oil at the wells was over four times as great in 1937 as in 1933.

The indicated demand for crude petroleum in the Gulf Coast district for 1938 was 179,253,000 barrels, the equivalent of 491,000 barrels per day. At this rate of demand the stocks of crude oil at the refineries and in pipe-line and tank-farm storage shown in table 20 are equivalent to 56 days' requirements.

The extent of activity in the Gulf Coast district is indicated by the data in table 22; 1,435 commercial oil wells were listed as completed in 1938, with an average initial daily production of 417 barrels per well.

## ROCKY MOUNTAIN DISTRICT

Crude oils of the Rocky Mountain district are divided conveniently into two kinds, "green" or light oil, and "black" or heavy oil. Up to the present the major portion of the production from the Rocky Mountain fields has been green oil. Until 1939 the Salt Creek field of Wyoming was the principal green-oil field, and most of the production of this region in the past has come from it. Production from the Lance Creek field, Wyoming, increased rapidly during 1938 and 1939, owing to discovery of new producing areas and new horizons, until it now exceeds the production of the Salt Creek field. Green oil is produced in a number of the smaller fields of the Rocky Mountain area such as Medicine Bow, Rock River, Lost Soldier, Grass Creek, Quealy, Elk Basin, Osage, and Big Muddy in Wyoming; and Cut Bank, Kevin-Sunburst, Pondera, Cat Creek, and Dry Creek in Montana.

These green oils contain from 10 to more than 40 percent of gasoline and varying proportions of paraffin wax. The refineries of the Rocky Mountain area produce kerosene, lubricants, paraffin wax, and fuel oils, in addition to gasoline, from these green oils.

The black oils of the Rocky Mountain area are to a great extent an undeveloped resource, and at present the principal products manufactured from them are asphalt and road oil. Although the potential daily output of black oils from wells already drilled is approximately 56,000 barrels, only an average of 13,000 barrels was produced daily in 1937. The small production is due to the limited market for oil of this type resulting from the almost prohibitive costs of refining these crude oils into marketable products other than asphalts.

Tables 23 to 26, inclusive, give data on production, movements, and prices of crude oil and wells drilled in the Rocky Mountain district.

### TABLE 23.—*Production of crude petroleum in the Rocky Mountain district, 1929–38*

[Thousands of barrels of 42 gallons]

| Year | Colorado | Montana | Northwestern New Mexico | Wyoming | Utah | Total |
|---|---|---|---|---|---|---|
| 1929 | 2,358 | 3,980 | 608 | 19,314 | [1] 7 | 26,267 |
| 1930 | 1,656 | 3,349 | 621 | 17,868 | [1] 7 | 23,501 |
| 1931 | 1,545 | 2,830 | 523 | 14,834 | [1] 7 | 19,739 |
| 1932 | 1,136 | 2,457 | 393 | 13,418 | [1] 6 | 17,410 |
| 1933 | 919 | 2,273 | 368 | 11,227 | [1] 13 | 14,800 |
| 1934 | 1,139 | 3,603 | 376 | 12,556 | 4 | 17,678 |
| 1935 | 1,560 | 4,603 | 370 | 13,755 | 3 | 20,291 |
| 1936 | 1,650 | 5,868 | 406 | 14,582 | 3 | 22,509 |
| 1937 | 1,605 | 5,805 | 388 | 19,166 | 2 | 26,966 |
| 1938 [2] | 1,412 | 4,907 | 354 | 19,004 | 12 | 25,686 |

[1] Includes Alaska.
[2] Subject to revision.

### TABLE 24.—*Stocks of Rocky Mountain crude petroleum, Dec 31, 1938*

[Thousands of barrels of 42 gallons]

| | |
|---|---|
| Stocks in refineries | 2,030 |
| Pipe-line and tank-farm stocks | 18,478 |
| Total stocks | 20,508 |

### TABLE 25.—*Value of crude petroleum at wells, 1933–37, in the Rocky Mountain district*

[Total in thousands of dollars; averages in dollars per barrel]

| | 1933 | | 1934 | | 1935 | | 1936 | | 1937 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Average | Total | Average | Total | Average | Total | Average | Total | Average |
| Colorado | 540 | $0.59 | 1,060 | $0.93 | 1,420 | $0.91 | 1,660 | $1.01 | 1,809 | $1.12 |
| Montana | 2,220 | .98 | 4,380 | 1.22 | 6,150 | 1.34 | 7,709 | 1.31 | 7,309 | 1.26 |
| Northwestern New Mexico | 320 | .87 | 400 | 1.06 | (1) | (1) | (1) | (1) | (1) | (1) |
| Wyoming | 6,570 | .59 | 10,550 | .84 | 11,730 | .85 | 13,700 | .94 | 18,860 | .98 |
| Utah | [2] 18 | [2] 1.38 | 4 | 1.06 | 4 | 1.33 | 5 | 1.69 | 3 | 1.50 |
| Total Rocky Mountain | 9,668 | | 16,391 | | 19,304 | | 23,065 | | 27,963 | |

[1] Included in Mid-Continent.
[2] Includes Alaska.

### TABLE 26.—*Oil and gas wells in 1937–38, in the Rocky Mountain district*

| State | Producing oil wells | | Wells drilled in 1938 | | | | |
|---|---|---|---|---|---|---|---|
| | Approximate number Dec. 31, 1937 | Average production per well per day | Oil | Gas | Dry | Total | Estimated average daily initial production per well |
| Colorado | 200 | 21.4 | 7 | 1 | 10 | 18 | 135 |
| Montana | 1,600 | 10.4 | 69 | 21 | 27 | 117 | 78 |
| Wyoming | 3,350 | 15.5 | 95 | 19 | 43 | 157 | 480 |
| Total | 5,150 | | 171 | 41 | 80 | 292 | |

Table 23 shows that the production of crude oil in the Rocky Mountain district decreased until 1933, then increased considerably until 1937, with a small decrease in 1938.

The indicated demand for crude oil in this region for 1938 was 29,687,000 barrels, equivalent to 81,000 barrels per day. The total stocks of crude oil, given in table 24, indicate a 253-day supply of oil to meet these demands.

According to table 25, the total value at the wells of the crude oil produced in 1937 was almost three times the value of that produced in 1933.

Table 26 indicates drilling activity during 1938. More wells were drilled in Colorado and Wyoming in 1938 than in 1937, but in Montana only about half as many were drilled in 1938 as in 1937.

## CALIFORNIA DISTRICT

Crude oils produced in California range in character from heavy, non-gasoline-bearing, high-asphalt-content, naphthene-base crude oils to light, high-gasoline-content, wax-bearing, intermediate-base oils. The heavy oils are used principally as fuel or road oils, whereas the entire range of petroleum products, except paraffin wax, is manufactured from the light crude oils. Many of the straight-run gasolines from California crude oils have high octane ratings, making "re-forming" unnecessary for the manufacture of motor fuels of good quality. A considerable volume of road oils and asphalts is manufactured from California crude oils. However, fuel oils are still the major product of California refineries in point of volume.

Tables 27 to 30, inclusive, give data on production, stocks, value at the wells, and wells drilled in California.

TABLE 27.—*Production of crude petroleum in California, 1929–38*

[Thousands of barrels of 42 gallons]

| | |
|---|---|
| 1929 | 292, 534 |
| 1930 | 227, 329 |
| 1931 | 188, 830 |
| 1932 | 178, 128 |
| 1933 | 172, 010 |
| 1934 | 174, 305 |
| 1935 | 207, 832 |
| 1936 | 214, 773 |
| 1937 | 238, 521 |
| 1938 [1] | 249, 749 |

[1] Subject to revision.

TABLE 28.—*Stocks of California crude petroleum, Dec. 31, 1938*

[Thousands of barrels of 42 gallons]

| | |
|---|---|
| Stocks at refineries | 10, 330 |
| Pipe-line and tank-form stocks | 24, 012 |
| Pipe-line and tank-farm stocks (heavy crude) | 16, 467 |
| Total stocks | 50, 809 |

TABLE 29.—*Value of crude petroleum at the wells, 1933–37, in California*

[Totals in thousands of dollars; averages in dollars per barrel]

| Year | Total | Average | Year | Total | Average |
|---|---|---|---|---|---|
| 1933 | 143, 300 | $0. 83 | 1936 | 215, 900 | $1. 01 |
| 1934 | 160, 700 | . 92 | 1937 | 242, 100 | 1. 02 |
| 1935 | 170, 600 | . 82 | | | |

TABLE 30.—*Oil and gas wells in 1937–38 in California*

| | |
|---|---|
| Producing wells: | |
| Approximate number, Dec. 31, 1937 | 13,460 |
| Average production per well per day | 50.9 |
| Wells drilled in 1938: | |
| Oil | 993 |
| Gas | 7 |
| Dry | 265 |
| Total | 1,265 |
| Estimated average daily initial production per well | 927 |

Table 27 shows that the volume of crude oil produced in California decreased from 1929 to 1933; then increased gradually until the 1938 production was only 15 percent less than that of 1929. Potential production in California probably will continue to increase, owing to the recent discovery of new producing fields and new horizons in old fields.

The indicated demand for crude petroleum in California for 1938 was 240,053,000 barrels, an average of 658,000 barrels per day. On this basis the stocks of refinable crude oil in California (34,342,000 barrels) on December 31, 1938, were adequate to supply 52 days' demand. The California district has the fewest number of days' supply in storage of any of the major oil-producing districts. The Lima-Indiana district, which has a relatively small production, had 26 days' supply in storage on that date.

## NATURAL GASOLINE

Beginning in the early years of the twenieth century the manufacture of natural gasoline has grown side by side with the petroleum-producing and petroleum-refining branches to the point where it is an important factor in the American petroleum industry.

"Natural gasoline" is the name given to certain liquid products extracted from natural gas by purely physical methods. These liquid constituents must be extracted from natural gas before it can be handled satisfactorily in pipe lines at the now-prevailing pressures of 400 to 600 pounds per square inch or higher, at which natural gas is transported. If the liquids were not extracted before the gas is put into pipe lines they probably would separate and collect in low places in the line and otherwise cause trouble.

The bulk of natural gasoline produced in the United States is blended at refineries with refinery gasoline, although in recent years an increasing tendency has developed to market certain grades of natural gasoline as finished motor fuel. Considerable quantities of propane and butane from natural gasoline are used as domestic fuels, and as raw material for manufacturing chemicals and high-octane motor fuel. These uses are discussed in later sections of this report. Quantities of natural gasoline blended at refineries in each refinery district are given in tables 33 to 42, inclusive, in section II of this report.

Statistics showing production, distribution, and consumption of natural gasoline are published monthly and annually by the Bureau of Mines, United States Department of the Interior.

## SUMMARY

Section I contains factual data relating to sources of production and stocks on hand of the raw materials of the petroleum-refining industry (crude petroleum and natural gasoline). Data given in tables have been interpreted to provide examples of inferences that can be drawn from them. Doubtless readers will derive additional information from further analysis of data given in the tables. More detailed figures on production, stocks, prices, and other aspects of supply of and demand for crude petroleum and petroleum products are given in monthly and annual publications of the Bureau of Mines, United States Department of the Interior.

## SECTION II. PETROLEUM REFINERIES IN THE UNITED STATES AND QUANTITIES OF PRINCIPAL PRODUCTS MANUFACTURED

The Bureau of Mines has published annual statistics on operations of petroleum refineries of the United States since 1916. To facilitate analysis of data the Bureau has divided the United States into 10 districts.

This section of the report gives data regarding the number of refineries in the United States and their distribution among the 10 refinery districts. Information is included for each district regarding capacity of refineries in operation, refining capacity shut down, and capacity of refining plants being built on January 1, 1938 (table 31). Similar information is given regarding cracking equipment (table 32). These data are taken from the annual review prepared by G. R. Hopkins, of the Bureau of Mines.

A change in the basis for reporting cracking capacity was made in the report for January 1, 1938. Until then cracking capacity had been given in terms of charging stocks that could be processed, in barrels per day. In table 32 cracking capacity is reported in barrels of cracked gasoline per day. Therefore, the data are not comparable directly with those reported on the former basis. However, the new basis of reporting is thought to be a more direct measure of the productive capacity of cracking plants.

A table for each of the 10 refinery districts shows a composite balance sheet of refinery operations in the district for 1932, 1933, 1937, and 1938. These tables list the quantity of raw materials used (domestic crude oil, imported crude oil, unfinished oils, and natural gasoline) and what was made from them. They also indicate how differences in supply and demand and other factors in the various districts influence refinery operations.

TABLE 31.—*Refinery capacity, Jan. 1, 1938, by districts* [1]

| Districts | Number | | | | Capacity (barrels per day) | | | |
|---|---|---|---|---|---|---|---|---|
| | Operating | Shutdown | Building | Total | Operating | Shutdown | Building | Total |
| 1. East Coast | 23 | 2 | -------- | 25 | 595,900 | 19,800 | 35,000 | 650,700 |
| 2. Appalachian | 38 | 5 | -------- | 43 | 136,450 | 18,850 | -------- | 155,300 |
| 3. Indiana-Illinois-Kentucky | 49 | 10 | 4 | 63 | 512,110 | 50,570 | 48,400 | 611,080 |
| 4. Oklahoma-Kansas | 51 | 16 | -------- | 67 | 390,580 | 76,870 | 7,500 | 474,950 |
| 5a. Texas Inland | 82 | 40 | -------- | 122 | 264,680 | 103,055 | 1,000 | 368,735 |
| 5b. Texas Gulf Coast | 30 | 1 | -------- | 31 | 906,500 | 9,500 | 94,200 | 1,010,200 |
| 6a. Louisiana Gulf Coast | 5 | -------- | 1 | 6 | 143,500 | -------- | 5,000 | 148,500 |
| 6b. Arkansas and Louisiana Inland | 13 | 3 | 2 | 18 | 99,500 | 11,500 | 11,000 | 122,000 |
| 7. Rocky Mountain | 73 | 29 | 3 | 105 | 102,366 | 12,260 | 4,000 | 118,626 |
| 8. California | 67 | 14 | -------- | 81 | 818,610 | 78,550 | 76,920 | 974,080 |
| Total | 431 | 120 | 10 | 561 | 3,970,196 | 380,955 | 283,020 | 4,364,171 |

[1] Hopkins, G. R., Petroleum Refineries, including Cracking Plants, in the United States, Jan. 1, 1938, Bureau of Mines Information Circular 7034, August 1938.

TABLE 32.—*Cracking capacity, Jan. 1, 1938, by districts* [1]

| Districts | Capacity, barrels of cracked gasoline per day | | | |
|---|---|---|---|---|
| | Operating | Shut down | Building | Total |
| 1. East Coast | 136,919 | 3.300 | 12,280 | 152,499 |
| 2. Applachian | 33,730 | 2,450 | 1,680 | 37,860 |
| 3. Indiana-Illinois-Kentucky | 161,350 | 18,810 | 10,735 | 190,895 |
| 4. Oklahoma-Kansas | 94,805 | 23,076 | 2,000 | 119,881 |
| 5a. Texas Inland | 62,935 | 9,700 | -------- | 72,635 |
| 5b. Texas Gulf Coast | 218,000 | 1,200 | 41,700 | 260,900 |
| 6a. Louisiana Gulf Coast | 26,700 | -------- | -------- | 26,700 |
| 6b. Arkansas and Louisiana Inland | 15,500 | 2,500 | 750 | 18,750 |
| 7. Rocky Mountain | 20,502 | 2,774 | 850 | 24.126 |
| 8. California | 82,720 | 16,000 | 16,065 | 114,785 |
| Total | 853,161 | 79,810 | 86,060 | 1,019.031 |

[1] Hopkins, G. R., Petroleum Refinieries, including Cracking Plants, in the United States, Jan. 1, 1938, Bureau of Mines Information Circular 7034, August 1938.

### EAST COAST REFINERY DISTRICT

As shown in table 31, on January 1, 1938, the East Coast district had 23 operating refineries with a total refinery capacity of 595,000 barrels per day, and refining equipment with charging capacity of 35,000 barrels per day was under construction. The equipment under construction represents approximately the increase in total refinery capacity in the district by comparison with total capacity on January 1, 1934. Refining capacity in operation on January 1, 1938, was less by 14,000 barrels per day than on January 1, 1934.

The East Coast refinery district ranks third among the 10 refinery districts in refinery capacity, in cracking capacity, and in capacity of cracking equipment under construction.

TABLE 33.—*Refinery operations in the East Coast refinery district, 1932–33 and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938 [1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 122, 380 | 132, 794 | 173, 737 | 156, 473 |
| Imported crude oil run to stills | 40, 154 | 34, 138 | 24, 343 | 24, 133 |
| Unfinished oils rerun | 2, 296 | | [2] 8, 258 | [2] 6, 991 |
| Natural gasoline blended | 641 | 1, 109 | 1, 540 | 1, 198 |
| Total input | 165, 471 | 168, 041 | 207, 878 | 188, 795 |
| Output: | | | | |
| Straight-run gasoline | 30, 558 | 32, 946 | 33, 419 | 30, 070 |
| Cracked gasoline | 37, 062 | 34, 481 | 46, 137 | 42, 279 |
| Natural gasoline | 641 | 1, 109 | 1, 540 | 1, 198 |
| Total gasoline | 68, 261 | 68, 536 | 81, 096 | 73, 547 |
| Kerosene | 7, 150 | 9, 677 | 11, 024 | 9, 208 |
| Gas oil and distillate fuel oil | 12, 992 | 15, 035 | 30, 020 | 28, 559 |
| Residual fuel oil | 49, 838 | 46, 719 | 55, 274 | 50, 722 |
| Still gas (oil equivalent) | 8, 734 | 9, 382 | 10, 339 | 9, 188 |
| Lubricants | 6, 712 | 7, 387 | 9, 360 | 7, 613 |
| Paraffin wax | 748 | 834 | 892 | 702 |
| Asphalt | 6, 546 | 5, 802 | 9, 155 | 9, 534 |
| Road oil | 620 | 747 | 903 | 331 |
| Petroleum coke | 928 | 1, 057 | 52 | 19 |
| Petrolatum | 36 | 133 | 147 | 790 |
| Medicinal oil | 81 | 97 | 130 | |
| Ink oil | 35 | 26 | | |
| Liquefied petroleum gas | | | 388 | |
| Other finished products | 73 | 80 | 103 | |
| Unfinished oils | | 1, 575 | | |
| Shortage | 2, 717 | 954 | [3] 1, 005 | [3] 1, 418 |
| Total output | 165, 471 | 168, 041 | 207, 878 | 188, 795 |

[1] Subject to revision.
[2] Includes net crude gasoline.
[3] Overage.

As shown in table 33 the largest change in quantity of products manufactured in the East Coast refinery district is in gas oil and distillate-fuel oils, which have nearly doubled since 1933, and the largest change in proportion is the reduction in petroleum coke to negligible quantities. Although the total output of all products in 1938 was less than in 1937, the quantity of asphalt manufactured in 1938 exceeded that manufactured in 1937. More than 80 percent of the medicinal oil made in United States refineries in 1937 was produced in the East Coast district. The remainder was made in California refineries.

On the basis of 1938 operations the East Coast district ranks first among the 10 refinery districts in production of paraffin wax and asphalt, second in kerosene and lubricants, and third in fuel oils and still gas (gas collected from cracking plants and other refinery equipment).

### APPALACHIAN REFINERY DISTRICT

Table 31 shows that the Appalachian district had 38 operating refineries with a combined capacity of 136,450 barrels per day on January 1, 1938; 5 refineries with operating capacity of 18,850 barrels per day were shut down;

and no refinery equipment was under construction. Operating cracking capacity was 33,730 barrels of cracked gasoline per day, and cracking equipment with capacity of 1,680 barrels per day was under construction.

The principal products of refineries in the Appalachian refinery district in 1938, in order of volume of production, were gasoline, lubricants, residual fuel oil, and kerosene (see table 34). The district ranked third in quantity of lubricants manufactured and second in paraffin wax, although it ranked only eighth in volume of crude oil run to stills. The principal change in quantity of products manufactured in 1938 in comparison with 1933 was the increase of 1,187,000 barrels of lubricants and of 1,869,000 barrels of cracked gasoline manufactured. More than 46 percent of the petrolatum manufactured in the United States in 1937 was made in refineries of the Appalachian district.

TABLE 34.—*Refinery operations in the Appalachian refinery district, 1932–33, and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938 [1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 34, 136 | 33, 567 | 40, 286 | 39, 180 |
| Unfinished oils rerun | | 3, 381 | 88 | 53 |
| Natural gasoline blended | 377 | 237 | 362 | 269 |
| Total input | 34, 513 | 37, 185 | 40, 736 | 39, 502 |
| Output: | | | | |
| Straight-run gasoline | 8, 412 | 8, 388 | 9, 911 | 8, 371 |
| Cracked gasoline | 8, 233 | 8, 871 | 9, 666 | 10, 740 |
| Natural gasoline blended | 377 | 237 | 362 | 269 |
| Total gasoline | 17, 022 | 17, 496 | 19, 939 | 19, 380 |
| Kerosene | 3, 289 | 2, 855 | 3, 220 | 2, 769 |
| Gas oil and distillate fuel oil | 1, 316 | 2, 601 | 2, 756 | 2, 446 |
| Residual fuel oil | 3, 357 | 4, 810 | 4, 315 | 4, 725 |
| Still gas (oil equivalent) | 2, 370 | 2, 366 | 2, 301 | 2, 187 |
| Lubricants | 4, 101 | 4, 576 | 6, 083 | 5, 763 |
| Paraffin wax | 304 | 247 | 312 | 296 |
| Asphalt | 638 | 486 | 563 | 653 |
| Road oil | 170 | 81 | 49 | 140 |
| Petroleum coke | 209 | 122 | 122 | 100 |
| Petrolatum | 147 | 175 | 200 | 170 |
| Black oil | 4 | | | |
| Acid oil | 12 | 6 | | |
| Absorption oil | | 16 | | |
| Other finished products | 47 | 61 | 48 | |
| Unfinished oils | 158 | | | |
| Shortage | 1, 369 | 1, 287 | 828 | 873 |
| Total output | 34, 513 | 37, 185 | 40, 736 | 39, 502 |

[1] Subject to revision.

## INDIANA-ILLINOIS-KENTUCKY REFINERY DISTRICTS

As is shown in table 31, the Indiana-Illinois-Kentucky district had 49 operating refineries with a charging capacity of 512,110 barrels of oil per day on January 1, 1938, 10 refineries with a charging capacity of 50,570 barrels per day were shut down and a charging capacity of 48,400 barrels per day (including 4 new refineries) was under construction. This district ranks second to the Texas Gulf Coast refinery district in cracking capacity in operation and in total cracking capacity.

Table 35 shows that gasoline is the principal product of the refineries in the Indiana-Illinois-Kentucky refinery district. The yield of gasoline in relation to crude oil run to stills in 1938 (55.8 percent) was the highest of any of the 10 refinery districts. In 1938 the district ranked first among the 10 refinery districts in quantity of petroleum coke produced, second in manufacture of gasoline, asphalt, still gas, and road oil, and third in quantity of kerosene manufactured. Fuel oils were second to gasoline in this district in point of quantity manufactured in 1938. The importance of still gas (gas collected from cracking stills and other refinery equipment) as a refinery product is shown in the table. Converting the volume of still gas recovered to its equivalent in oil on a basis of heating value gives a figure more than 72 percent greater than the quantity of kerosene manufactured in the area.

TABLE 35.—*Refinery operations in the Indiana-Illinois-Kentucky refinery district, 1932–33 and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938[1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 106, 758 | 117, 073 | 161, 243 | 163, 140 |
| Unfinished oils rerun | ---------- | ---------- | [2] 409 | [2] 694 |
| Natural gasoline blended | 1, 859 | 1, 785 | 4, 077 | 4, 488 |
| Total input | 108, 617 | 118, 858 | 168, 729 | 168, 322 |
| Output: | | | | |
| Straight-run gasoline | 28, 621 | 25, 982 | 39, 482 | 39, 477 |
| Cracked gasoline | 31, 417 | 36, 818 | 51, 850 | 51, 546 |
| Natural gasoline | 1, 859 | 1, 785 | 4, 077 | 4, 488 |
| Total gasoline | 61, 897 | 64, 585 | 95, 409 | 95, 511 |
| Kerosene | 3, 517 | 4, 221 | 6, 238 | 7, 096 |
| Gas oil and distillate fuel oil | 8, 008 | 8, 991 | 17, 033 | 17, 397 |
| Residual fuel oil | 14, 500 | 18, 059 | 24, 953 | 23, 319 |
| Still gas (oil equivalent) | 8, 191 | 9, 638 | 12, 377 | 12, 244 |
| Lubricants | 2, 002 | 1, 832 | 3, 457 | 2, 609 |
| Paraffin wax | 152 | 92 | 154 | 113 |
| Asphalt | 1, 982 | 2, 322 | 3, 920 | 3, 703 |
| Road oil | 2, 337 | 1, 434 | 1, 854 | 1, 750 |
| Petroleum coke | 3, 716 | 3, 100 | 3, 634 | 4, 889 |
| Petrolatum | 34 | 26 | 37 | 295 |
| Acid oil | 6 | 3 | ---------- | |
| Liquefied petroleum gas | ---------- | ---------- | 140 | |
| Other finished products | 285 | 141 | 221 | |
| Unfinished oils | 1, 380 | 3, 452 | ---------- | ---------- |
| Shortage | 610 | 962 | [3] 698 | [3] 604 |
| Total output | 108, 617 | 118, 858 | 168, 729 | 168, 322 |

[1] Subject to revision.
[2] Includes net crude gasoline rerun.
[3] Overage.

## OKLAHOMA-KANSAS REFINERY DISTRICT

Statistics on refinery capacity for the Oklahoma-Kansas district illustrate the shift that has taken place in situation of petroleum refineries. On January 1, 1934, this district had 66 operating refineries with an aggregate capacity of 445,870 barrels of oil per day; 22 refineries with a capacity of 59,280 barrels per day were shut down; and 2 refineries with capacity of 3,600 barrels were under construction. Four years later, on January 1, 1938, the district had 51 operating refineries with an aggregate capacity of 390,580 barrels per day, and 16 refineries with a capacity of 76,870 barrels were shut down. Thus it appears that during the 4-year period the net change in refinery capacity in the district has been a reduction in total charging capacity of 41,300 barrels per day, and in total number of refineries from 90 to 67. In spite of the reduction in refinery capacity, the total input in refineries in the district in 1938 was 15.5 percent greater than in 1933.

The principal products of refineries in this district are gasoline, residual fuel oil, gas oil and distillate fuel oil, and kerosene. The district ranked second among the 10 refinery districts in production of petroleum coke in 1938. The principal change in quantities of products manufactured in 1933 and 1938 is the increase of 10,682,000 barrels in quantity of gasoline manufactured (table 36), and the largest proportional change is the more than four-fold increase in quantity of asphalt manufactured. The quantity of gas oil and distillate fuel oil manufactured in 1938 was 54 percent greater than in 1933.

TABLE 36.—*Refinery operation in the Oklahoma-Kansas refinery district, 1932–33 and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938[1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 87, 170 | 96, 541 | 121, 238 | 111, 143 |
| Unfinished oils rerun | 2, 123 | 513 | 412 | 986 |
| Natural gasoline blended | 4, 847 | 4, 968 | 5, 895 | 5, 772 |
| Total input | 94, 140 | 102, 022 | 127, 545 | 117, 901 |
| Output: | | | | |
| Straight-run gasoline | 27, 185 | 27, 087 | 36, 897 | 33, 752 |
| Cracked gasoline | 19, 493 | 22, 982 | 26, 859 | 26, 195 |
| Natural gasoline | 4, 847 | 4, 968 | 5, 895 | 5, 772 |
| Total gasoline | 51, 525 | 55, 037 | 69, 576 | 65, 719 |
| Kerosene | 6, 564 | 6, 823 | 7, 396 | 6, 960 |
| Gas oil and distillate fuel oil | 6, 994 | 7, 267 | 11, 434 | 11, 163 |
| Residual fuel oil | 16, 706 | 19, 539 | 21, 819 | 19, 101 |
| Still gas (oil equivalent) | 3, 618 | 4, 557 | 6, 968 | 5, 775 |
| Lubricants | 2, 476 | 2, 435 | 3, 659 | 2, 962 |
| Paraffin wax | 103 | 104 | 120 | 110 |
| Asphalt | 193 | 367 | 1, 475 | 1, 599 |
| Road oil | 1, 095 | 822 | 688 | 830 |
| Petroleum coke | 1, 333 | 1, 390 | 1, 181 | 1, 068 |
| Petrolatum | 7 | 20 | 32 | 120 |
| Absorption oil | 43 | 46 | 74 | |
| Other finished products | 42 | 99 | 46 | |
| Crude gasoline | -------- | -------- | 1, 292 | 386 |
| Shortage | 3, 441 | 3, 516 | 1, 785 | 2, 108 |
| Total input | 94, 140 | 102, 022 | 127, 545 | 117, 901 |

[1] Subject to revision.

## TEXAS INLAND REFINERY DISTRICT

The Texas Inland district is another that has lost ground in the shift in refinery operations from inland to coastal points. On January 1, 1938, the district had 82 operating refineries with an aggregate capacity of 264,680 barrels per day, whereas on January 1, 1934, there were 120 operating refineries in the district with aggregate capacity of 328,244 barrels. Although the Texas Inland refinery district ranked only sixth in total input of refineries in 1933 and in 1937 it had more refinery capacity shut down than any other of the 10 refinery districts of the United States. On January 1, 1938, nearly 28 percent of the total refinery capacity in the district was inoperative.

The Texas Inland refinery district ranked sixth in volume of crude oil run to stills in 1938. Gasoline and residual fuel oil are the principal products of its refineries (table 37). The increased quantity of gasoline manufactured in 1938 compared with 1933 nearly equals the difference in total input in 1938 and 1933. The greatest proportional change in quantity of products manufactured is found in road oil; a total of 268,000 barrels was made in 1932 and 1933, in contrast to only 4,000 barrels of road oil manufactured in the 2-year period 1937–38. On the other hand, 8 times as much asphalt was manufactured in 1938 as in 1933.

TABLE 37.—*Refinery operations in the Texas Inland refinery district, 1932–33 and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938 [1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 49,435 | 57,454 | 75,415 | 66,923 |
| Unfinished oils rerun | 197 | --- | ------ | 83 |
| Natural gasoline blended | 3,248 | 3,404 | 5,816 | 6,625 |
| Total input | 52,880 | 60,858 | 81,231 | 73,631 |
| Output: | | | | |
| Straight-run gasoline | 16,181 | 19,269 | 23,043 | 20,791 |
| Cracked gasoline | 8,459 | 8,273 | 15,532 | 15,348 |
| Natural gasoline | 3,248 | 3,404 | 5,816 | 6,625 |
| Total gasoline | 27,888 | 30,946 | 44,391 | 42,764 |
| Kerosene | 2,311 | 3,218 | 3,515 | 2,985 |
| Gas oil and distillate fuel oil | 2,348 | 2,972 | 5,423 | 4,217 |
| Residual fuel oil | 15,461 | 17,654 | 20,914 | 15,871 |
| Still gas (oil equivalent) | 1,158 | 1,218 | 3,537 | 2,999 |
| Lubricants | 235 | 284 | 229 | 213 |
| Paraffin wax | 11 | 11 | 12 | 7 |
| Asphalt | ------ | 185 | 612 | 1,499 |
| Road oil | 201 | 67 | 3 | 1 |
| Petroleum coke | 324 | 141 | 531 | 507 |
| Absorption oil | 79 | 70 | 59 | 58 |
| Liquefied petroleum gas | ------ | ------ | 5 | |
| Other finished products | 33 | 6 | 104 | |
| Crude gasoline | ------ | ------ | 122 | ------ |
| Other unfinished oils | ------ | 568 | 289 | 853 |
| Shortage | 2,831 | 3,518 | 1,485 | 1,657 |
| Total output | 52,880 | 60,858 | 81,231 | 73,631 |

[1] Subject to revision.

## TEXAS GULF COAST REFINERY DISTRICT

Greater advances have been made in the Texas Gulf Coast district since 1933 than in any of the other refinery districts. On January 1, 1934, it had 17 operating refineries (with a total capacity of 536,500 barrels of oil per day); 25,000 barrels per day of refinery capacity under construction; third rank in total refinery capacity among the 10 refinery districts. However, on January 1, 1938, the district had 30 operating refineries, with total capacity of 906,500 barrels per day; had 94,200 barrels of refinery capacity under construction; and ranked first in refinery capacity and in cracking capacity in operation and under construction. On January 1, 1938, operating refineries in this district had an average daily rated capacity of 30,200 barrels of oil, the largest average capacity of any of the 10 refinery districts.

Nearly 54 percent more crude oil was run to stills in Texas Gulf Coast refineries in 1938 than in California refineries, which ranked second in this respect, and the total quantity of products manufactured in 1938 was nearly twice the corresponding figure for 1933 (table 38). Gasoline was the principal product of refineries in the Texas Gulf Coast district in point of quantity manufactured in 1938. The combined quantities of residual fuel oil, gas oil and distillate fuel oil, and kerosene, which ranked next in order of quantity produced, were only slightly greater than the quantity of gasoline manufactured. The district ranked first among the 10 refinery districts in quantity of gasoline, kerosene, lubricants, gas oil and distillate fuel oil, and still gas manufactured; second in residual fuel oil; and third in paraffin wax and petroleum coke. Despite the greater quantity of crude oil run to stills, the production of petroleum coke in 1938 was less than half that in 1933. Although this refinery district includes the Texas Gulf Coast oil-producing district, in which large volumes of asphalt-bearing oils are produced, and although the district is near sources of imported asphalt-bearing oils, the district ranked only seventh in production of asphalt and road oils in 1938. This circumstance apparently reflects the effect of demand on manufacture of these products. Although conditions apparently favor manufacture of asphalts and road oils in the Gulf Coast districts, the small nearby demand inhibits production.

TABLE 38.—*Refinery operation in the Texas Gulf Coast refinery district, 1932–33 and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938[1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 146, 161 | 160, 215 | 281, 406 | 306, 339 |
| Imported crude oil run to stills | 982 | 476 | 608 | 1, 567 |
| Unfinished oils rerun | ------ | ------ | 577 | [2] 590 |
| Natural gasoline blended | 3, 201 | 2, 512 | 6, 730 | 6, 063 |
| Total input | 150, 344 | 163, 203 | 289, 321 | 314, 559 |
| Output: | | | | |
| Straight-run gasoline | 29, 592 | 30, 902 | 45, 775 | 52, 033 |
| Cracked gasoline | 35, 252 | 37, 589 | 73, 383 | 81, 567 |
| Natural gasoline | 3, 201 | 2, 512 | 6, 730 | 6, 063 |
| Total gasoline | 68, 045 | 71, 003 | 125, 888 | 139, 663 |
| Kerosene | 9, 882 | 11, 345 | 20, 351 | 22, 357 |
| Gas oil and distillate fuel oil | 16, 219 | 17, 370 | 39, 385 | 47, 529 |
| Residual fuel oil | 35, 176 | 40, 074 | 73, 223 | 73, 774 |
| Still gas (oil equivalent) | 9, 702 | 10, 574 | 17, 893 | 19, 039 |
| Lubricants | 4, 761 | 4, 980 | 7, 929 | 7, 628 |
| Paraffin wax | 104 | 159 | 188 | 215 |
| Asphalt | 791 | 859 | 1, 246 | 1, 193 |
| Road oil | 92 | 182 | 293 | 235 |
| Petroleum coke | 1, 720 | 1, 492 | 564 | 705 |
| Petrolatum | 4 | 3 | 12 | 104 |
| Absorption oil | 2 | 6 | 2 | |
| Liquefied petroleum gas | 2 | ------ | 37 | |
| Other finished products | 25 | 30 | 245 | |
| Crude gasoline | ------ | ------ | 255 | ------ |
| Other unfinished oils | 1, 419 | 1, 695 | ------ | 543 |
| Shortage | 2, 402 | 3, 431 | 1, 810 | 1, 574 |
| Total output | 150, 344 | 163, 203 | 289, 321 | 314, 559 |

[1] Subject to revision.
[2] Net crude gasoline rerun.

## LOUISIANA GULF COAST REFINERY DISTRICT

On January 1, 1938, the Louisiana Gulf Coast district ranked seventh among the 10 refinery districts in rated capacity of operating refineries and eighth in operating capacity of cracking plants. The 5 operating refineries in the district were rated at a total capacity of 143,500 barrels of oil per day, and a refinery with a capacity of 5,000 barrels per day was reported as under construction at that time. In contrast to conditions on January 1, 1934, when more than 30 percent of the installed cracking equipment in the district was reported shut down, no cracking plant was reported shut down on January 1, 1938.

The district ranked seventh in quantity of crude oil run to stills in 1938, and (in contrast to the neighboring Texas Gulf district) the increase in quantity of products manufactured in 1938 over 1933 was only 21 percent (table 39). The principal products of refineries in this district in 1938 were gasoline, residual fuel oil, gas oil and distillate fuel oil, and kerosene. The largest proportionate increase in volume of products in 1938 compared with 1933 was the increased quantity of lubricants manufactured. In contrast to operations in other refinery districts the quantity of petroleum coke produced in 1938 was considerably greater than in 1933. The percentage yield of kerosene in this district in 1938 (12.9 percent) is the highest in any of the 10 refinery districts.

As in the neighboring Texas Gulf Coast district, manufacture of asphalt and road oil was of little consequence, although asphalt-bearing oils are produced in the district and were readily available from foreign sources.

TABLE 39.—*Refinery operations in the Louisiana Gulf Coast refinery district, 1932–33 and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938 [1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 34, 668 | 38, 180 | 49, 697 | 46, 416 |
| Imported crude oil run to stills | 1, 165 | 854 | 1, 045 | 487 |
| Unfinished oils rerun | 114 | | [2] 230 | [2] 372 |
| Natural gasoline blended | 834 | 284 | 835 | 382 |
| Total input | 36, 801 | 39, 318 | 51, 807 | 47, 657 |
| Output: | | | | |
| Straight-run gasoline | 7, 618 | 6, 955 | 8, 669 | 8, 803 |
| Cracked gasoline | 7, 381 | 7, 221 | 8, 737 | 7, 859 |
| Natural gasoline | 843 | 284 | 835 | 382 |
| Total gasoline | 15, 833 | 14, 460 | 18, 241 | 17, 044 |
| Kerosene | 3, 909 | 3, 896 | 5, 927 | 6, 037 |
| Gas oil and distillate fuel oil | 2, 526 | 4, 136 | 7, 800 | 7, 450 |
| Residual fuel oil | 10, 306 | 11, 895 | 13, 212 | 10, 806 |
| Still gas (oil equivalent) | 1, 261 | 1, 499 | 1, 993 | 2, 290 |
| Lubricants | 298 | 386 | 1, 246 | 1, 097 |
| Paraffin wax | 182 | 205 | 100 | 70 |
| Asphalt | 1, 005 | 551 | 1, 254 | 1. 355 |
| Road oil | 99 | 86 | 126 | 15 |
| Petroleum coke | 328 | 188 | 83 | 303 |
| Liquefied petroleum gas | | | 4 | 47 |
| Other finished products | 15 | 6 | 36 | |
| Unfinished oils | | 971 | 1, 000 | 462 |
| Shortage | 1, 039 | 1, 039 | 785 | 681 |
| Total output | 36, 801 | 39, 318 | 51, 807 | 47, 657 |

[1] Subject to revision.
[2] Net crude gasoline rerun.

## ARKANSAS AND LOUISIANA INLAND REFINERY DISTRICT

On January 1, 1938, Arkansas and Louisiana Inland was the smallest of the 10 refinery districts in point of refinery capacity and cracking capacity. The increase in operating capacity in the district since 1933 has not been as great as in the Rocky Mountain district, and that district was in ninth place on January 1, 1938.

The Arkansas and Louisiana Inland refinery district also ranked lowest in quantity of products manufactured in 1938. The most significant changes in quantity, as shown in table 40, are (1) the increase in quantity of lubricants manufactured in the district from 116,000 barrels in 1933 to 452,000 in 1938 and (2) the increase in quantity of kerosene from 773,000 barrels in 1933 to 2,139,000 in 1938.

TABLE 40.—*Refinery operations in the Arkansas and Louisiana Inland refinery district, 1932–33 and 1937–38*

[Thousands of barrels of 429 gallons]

| Product | 1932 | 1933 | 1937 | 1938 [1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 18, 297 | 18, 485 | 24, 912 | 24, 089 |
| Unfinished oils rerun | 86 | 20 | | [2] 6 |
| Natural gasoline blended | 804 | 407 | 731 | 737 |
| Total input | 19, 187 | 18, 912 | 25, 643 | 24, 832 |
| Output: | | | | |
| Straight-run gasoline | 4, 082 | 4, 245 | 6, 148 | 6, 407 |
| Cracked gasoline | 3, 523 | 3, 740 | 4, 291 | 3, 631 |
| Natural gasoline | 804 | 407 | 731 | 737 |
| Total gasoline | 8, 409 | 8, 932 | 11, 170 | 10, 775 |
| Kerosene | 718 | 773 | 1, 787 | 2, 139 |
| Gas oil and distillate fuel oil | 1, 849 | 1, 830 | 2, 428 | 2, 341 |

[1] Subject to revision.
[2] Net crude gasoline rerun.

TABLE 40.—*Refinery operations in the Arkansas and Louisiana inland refinery district, 1932–33 and 1937–38*—Continued

| Project | 1932 | 1933 | 1837 | 1938 [1] |
|---|---|---|---|---|
| Output—Continued. | | | | |
| Residual fuel oil | 6, 147 | 6, 010 | 6, 215 | 5, 697 |
| Still gas (oil equivalent) | 515 | 552 | 899 | 552 |
| Lubricants | 168 | 116 | 467 | 452 |
| Paraffin wax | ------ | ------ | 6 | 1 |
| Asphalt | 368 | 448 | 896 | 941 |
| Road oil | 152 | 129 | 371 | 417 |
| Petroleum coke | 12 | 12 | 10 | 6 |
| Ink oil | ------ | 18 | ------ | ------ |
| Other finished products | 94 | 5 | 10 | 1 |
| Crude gasoline (net) | ------ | ------ | 6 | ------ |
| Other unfinished oils | ------ | ------ | 624 | 687 |
| Shortage | 755 | 627 | 754 | 823 |
| Total output | 19, 187 | 18, 912 | 25, 643 | 24, 832 |

## ROCKY MOUNTAIN REFINERY DISTRICT

The Rocky Mountain district is characterized by small refineries. Table 31 shows that on January 1, 1938, the aggregate capacity of its 73 operating refineries was 102,366 barrels per day, which indicates an average daily capacity of slightly more than 1,400 barrels. The average daily capacity of the 29 shut-down refineries was even less—approximately 425 barrels. The district ranks ninth in total refinery capacity and in cracking capacity.

The influence of the increased use of asphalt and road oil in the Rocky Mountain area is seen in the marked increase in asphalt manufacture from 19,000 barrels in 1933 to 538,000 in 1938 and the 100-percent larger quantity of road oil manufactured in 1938 than in 1933.

Although the total quantity of products manufactured at petroleum refineries in the Rocky Mountain district is not large, the 70-percent increase in quantity in 1938 compared with 1933 (table 41) indicates that this inland refining district is not falling behind.

TABLE 41.—*Refinery operations in the Rocky Mountain refinery district, 1932–33 and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938 [1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 13, 934 | 14, 209 | 23, 365 | 24, 791 |
| Unfinished oils rerun | ------ | ------ | 473 | ------ |
| Natural gasoline blended | 991 | 819 | 826 | 803 |
| Total input | 14, 925 | 15, 028 | 24, 664 | 25, 594 |
| Output: | | | | |
| Straight-run gasoline | 3, 722 | 3, 630 | 6, 860 | 7, 360 |
| Cracked gasoline | 3, 280 | 3, 625 | 5, 778 | 5, 756 |
| Natural gasoline | 991 | 819 | 826 | 803 |
| Total gasoline | 7, 993 | 8, 074 | 13, 464 | 13, 919 |
| Kerosene | 506 | 570 | 796 | 810 |
| Gas oil and distillate fuel oil | 650 | 776 | 1, 462 | 1, 689 |
| Residual fuel oil | 2, 760 | 2, 858 | 4, 439 | 4, 916 |
| Still gas (oil equivalent) | 681 | 834 | 1, 344 | 1, 227 |
| Lubricants | 178 | 172 | 305 | 205 |
| Paraffin wax | 35 | 25 | 79 | 41 |
| Asphalt | 21 | 19 | 697 | 538 |
| Road oil | 826 | 619 | 1, 111 | 1, 238 |
| Petroleum coke | 456 | 335 | 354 | 329 |
| Petrolatum | 1 | 9 | 6 | 97 |
| Liquefied petroleum gases | ------ | ------ | 3 | |
| Other finished products | 1 | 11 | 108 | |
| Crude gasoline | ------ | ------ | 3 | 2 |
| Other unfinished oils | 514 | 218 | ------ | 78 |
| Shortage | 303 | 508 | 493 | 505 |
| Total output | 14, 925 | 15, 028 | 24, 664 | 25, 594 |

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[1] Subject to revision.

### CALIFORNIA REFINERY DISTRICT

The State of California is a refinery district in itself, ranks second among the 10 refinery districts in quantity of products manufactured and in refinery capacity, and is fifth in cracking capacity. On January 1, 1938, there were 67 operating refineries in the State with a rated capacity of 818,610 barrels of oil per day, and refinery equipment with rated capacity of 76,920 barrels per day was under construction. The cracking equipment in operation had a rated capacity of 82,720 barrels of cracked gasoline per day and cracking equipment with a capacity of 16,065 barrels per day was under construction.

In 1938 the State ranked first among the refinery districts in quantity of residual fuel oil and road oil manufactured, second in gas oil and distillate fuel oil, and third in gasoline and asphalt. The quantity of road oil manufactured in 1938 was more than twice (table 42), and the quantity of asphalt manufactured nearly twice, the quantity for 1933.

This is the only one of the 10 refinery districts in which gasoline is not the largest commodity in point of volume manufactured. The volume of residual fuel oil produced in 1938 exceeded the volume of gasoline by 8,500,000 barrels. The percentage yield of residual fuel oil (42.9) was far greater than in any other district.

TABLE 42.—*Refinery operations in California, 1932–33 and 1937–38*

[Thousands of barrels of 42 gallons]

| Product | 1932 | 1933 | 1937 | 1938 [1] |
|---|---|---|---|---|
| Input: | | | | |
| Domestic crude oil run to stills | 164, 737 | 157, 268 | 203, 145 | 200, 334 |
| Unfinished oils rerun | 516 | 18 | 1, 312 | |
| Natural gasoline | 9, 530 | 9, 821 | 12, 569 | 13, 624 |
| Total input | 174, 783 | 167, 107 | 217, 026 | 213, 958 |
| Output: | | | | |
| Straight-run gasoline | 39, 415 | 36, 218 | 41, 495 | 38, 354 |
| Cracked gasoline | 16, 805 | 17, 023 | 25, 903 | 25, 550 |
| Natural gasoline | 9, 530 | 9, 821 | 12, 569 | 13, 624 |
| Total gasoline | 65, 750 | 63, 062 | 79, 967 | 77, 528 |
| Kerosene | 5, 990 | 5, 599 | 5, 054 | 4, 219 |
| Gas oil and distillate fuel oil | 16. 565 | 17, 942 | 28, 965 | 28, 983 |
| Residual fuel oil | 71, 032 | 69, 901 | 87, 700 | 86, 041 |
| Still gas (oil equivalent) | 4, 675 | 4, 592 | 6, 567 | 6, 909 |
| Lubricants | 1, 502 | 1, 607 | 2, 586 | 2, 284 |
| Asphalt | 2, 068 | 1, 718 | 3, 183 | 3, 144 |
| Road oil | 1, 287 | 1, 367 | 2, 689 | 2, 831 |
| Petroleum coke | 97 | 63 | 2 | 85 |
| Absorption oil | 6 | | 37 | 239 |
| Medicinal oil | 23 | 8 | 32 | |
| Specialties | 82 | 43 | 41 | |
| Other finished products | 521 | 291 | 75 | |
| Crude gasoline | | | 109 | 101 |
| Other unfinished oils | | | | 597 |
| Shortage | 5, 185 | 914 | 19 | 997 |
| Total output | 174, 783 | 167, 107 | 217, 026 | 213, 958 |

[1] Subject to revision.

## SECTION III. PETROLEUM-REFINING TECHNOLOGY

### EARLY REFINING METHODS

Because of its chemical constitution crude petroleum has few uses in the raw or unrefined state. It consists predominantly of hydrocarbon compounds ranging from highly volatile materials boiling at or near atmospheric temperature to solids or extremely viscous fluids that will not boil but will decompose at approximately 800° F. and above.

The wide range of boiling points of the constituents of petroleum is used to separate it into usable products. The first process devised for refining petroleum—distillation—is still the basic operation in modern refineries.

In the early days of petroleum refining, crude oil was charged to batch-operated "cheese-box" stills, in which the lightest portions were removed by distillation. This fraction, consisting of gasoline and kerosene, was exposed to weather to remove the more inflammable material (gasoline), thereby producing a kerosene suitable for domestic lighting. Later, with the introduction of internal-combustion engines, gasoline superseded kerosene as the most important product, and the heavier portions of the crude oil were processed for lubricants as well. Lubricating-oil manufacture at that time consisted essentially of the following steps:

1. After gasoline, kerosene, and intermediate distillates had been removed, the crude oil was distilled further with steam to recover the low-viscosity lubricating-oil fractions.
2. These fractions were chilled and filtered through plate filter presses to remove crystalline wax. The dewaxed oils, known as pressed distillate, were processed further to make finished oils called "neutrals."
3. The residue left in the still after steam distillation (often called "steam-cylinder stock") was treated with sulfuric acid, diluted with naphtha, and chilled, and the "petrolatum" type of wax was allowed to settle. At a later period, centrifuges were used to obtain more rapid separation of the wax from the oil. The dewaxed residuum was filtered through fullers earth to produce a heavy lubricating stock called "bright stock."
4. By blending different proportions of bright stock and neutrals, lubricants of different consistencies or viscosities were made.

With the increased demand for petroleum products, the mechanical equipment used in petroleum refineries was improved. The batch-operated cheese-box and shell stills were replaced by continuously operated "batteries" of stills. A battery consisted of a series of interconnecting shell stills through which the oil charge was pumped continuously. Each succeeding still was heated to a higher temperature than the one preceding it, so that succeedingly heavier, higher-boiling material was distilled from the oil as it passed down the series until a heavy residuum was formed and removed from the last still of the battery. Although the type of products removed from each still varied between different refineries, depending on the character of the crude oil being processed and the products desired, a typical range of products from a five-still battery was: Still 1, light gasoline; still 2, heavy gasoline; still 3, kerosene; still 4, light gas oil; still 5, heavy gas oil, the remainder of the crude oil being pumped as a liquid from the bottom of the fifth still.

If lubricants were being manufactured in the refinery, the "bottoms" (residue from the "crude battery" described above) were run to one or more "steam reducing" stills of shell type, usually batch operated. The stills were fired as in the crude battery, but in addition live steam was bubbled through the hot oil, reducing the temperature necessary to vaporize the oil. Usually one or more light lubricating-oil distillates were obtained. Reducing stills using steam were employed also to reduce the residue from asphalt-bearing crude oils to desired asphaltic products.

Distillation provided a means of separating different boiling ranges of material from the crude oil to produce usable products, but the efficiency of these separations was poor owing to "carry over" of heavy material with the lighter vapors by entrainment. In the early refining equipment the degree of separation depended principally on the rate of distillation. As the demand for petroleum products increased, distillation processes were accelerated, with the result that separation between products was even poorer.

To correct this situation fractionating towers (vertical, cylindrical drums containing packing material, such as stones, iron chains, and short pieces of iron pipe) were placed between the vapor outlets of the stills and the condensers. Towers containing baffles, perforated plates, or more efficient types of packing such as "Lessing" or "Raschig" rings also were used.

These fractionating towers exercised a scrubbing action upon the vapors passing through them, resulting in better separation of the distillates. Upon entering the bottom of the tower the distilled vapors came into contact with the packing material, causing the entrained liquid to cling to the surface of the packing and the heaviest part of the vapor to condense. Because of the intimate contact between the uprising vapor and the downflowing liquid, some fractionation of products was obtained, resulting in improvement of the quality of products.

The petroleum-refining industry underwent considerable change following inception of the first "cracking" process in 1913. Before that time the quantity and quality of products obtained by refining depended entirely on the character of the crude oil, but cracking provided a means of increasing the yield of gasoline from a crude oil by decomposition of the heavier portions of the oil into gasoline.

The first cracking stills were of the shell type, but were built of heavier material than the stills used for ordinary distillation to withstand higher temperatures and pressures. In the first units, gas oil was charged to the still, the vapor-line valve was closed, and heat was applied until a predetermined pressure was attained. The vapor-line valve then was opened sufficiently and controlled to maintain the pressure. Heating of the still was continued until the contents were reduced to a heavy oil and a small quantity of coke. The recovered distillate, called "cracked" or "pressure" distillate, was rerun to produce gasoline and some heavier material. The noncondensable gas produced by cracking was blown to the air or, at a later period, used as refinery fuel.

## MODERN REFINING PROCESSES

The equipment in modern refineries has changed considerably from that previously described. The tendency in recent years has been to build continuous large-capacity units capable of yielding products of high and unvarying quality with minimum fuel and labor requirements and loss of material. The degree to which this practice has succeeded is indicated by the fact that the price of petroleum products (exclusive of taxes) to the consuming public has decreased steadily, while their quality has greatly improved.

Some of the more important changes in refinery equipment and processes are described in the following paragraphs:

Modern "pipe" or "tube" stills have replaced batch and continuously operated shell stills, and single units can handle 30,000 or more barrels of crude oil a day. A pipe still consists of a series of pipes or tubes distributed according to heat requirements inside a furnace. Oil is heated to a temperature somewhat higher than the boiling point of the highest-boiling constituent that it is desired to vaporize while the oil is being pumped through the tubes at a velocity high enough to prevent local overheating and formation of coke. The hot oil and vapor pass from the still into a fractionating tower where the products are separated. Careful design of the still and furnace is important to assure that the maximum efficiency of combustion be obtained in the furnace and the transfer of heat from the combustion gases to the oil be as complete as possible. The manufacturers of still tubes had to solve many problems before they could supply alloy steels capable of withstanding the stresses and strains developed under high temperature and pressure conditions and the corrosive action of sulfur compounds and other ingredients of some oils.

Pipe stills also have been adopted as a means of heating oil for modern cracking processes. The stills differ from pipe stills for crude oil only in the type of materials used, as they must withstand higher pressures and temperatures and more severe corrosive action than crude-oil stills.

Whereas gas oil was used as charging stock for the original cracking processes, any available material may now be cracked. Straight-run gasolines are "reformed" or cracked to increase their octane rating; gas oils, kerosene distillates, wax distillates, lubricating distillates, reduced crude oil, or the entire crude oil may be cracked in modern equipment. Heavy fuel oils sometimes are cracked mildly to lower their viscosity to produce a more marketable product. This process is called "viscosity breaking."

Cracking processes often are referred to as being divided into two types—vapor phase and liquid phase. In vapor-phase procedure the cracking stock is vaporized, and the vapors are subjected to high temperatures, usually at about atmospheric pressure. In liquid-phase procedure, pressures sometimes are maintained as high as 2,000 pounds per square inch, although those of 600 to 1,000 pounds are more common. Temperatures of vapor-phase cracking range from 1,100° to 1,400° F., whereas those of liquid-phase processes seldom exceed 1,100° F., 900° to 1,000° F. being normal. The cracking temperatures used depend on the charging stock, lighter stocks requiring the higher temperatures to obtain comparable yields of gasoline.

The cracked products from liquid-phase and vapor-phase cracking processes usually have somewhat different characteristics. Vapor-phase cracked gasoline ordinarily has the higher antiknock value but contains more gums and gum-forming constituents. Vapor-phase cracking usually yields greater quantities of cracked gases and smaller amounts of gasoline than liquid-phase cracking.

The operation of a cracking plant is similar to that for crude-oil distillation; however, temperature conditions in the still are more severe, and some plants are operated at high pressures that may place additional strains upon the equipment. The mechanical accessories for the two operations also are about the same, but cracking plants may have one or two additional pieces of equipment not found in those used for crude-oil distillation. Cracking plants may have a "reaction chamber" in the system between the still and fractionating tower. The reaction chamber or "soaking drum," as it is sometimes called, ordinarily is held under pressure at a temperature only a few degrees lower than that of the still outlet. The purpose of this equipment is to provide a space where the heated cracking stock may remain at a cracking temperature long enough to complete the desired cracking reaction. A second piece of equipment, usually called an "evaporator," may be installed between the reaction chamber and the tower. It is a vertical cylindrical drum that may or may not contain baffles or plates and separates heavy oil or "tar" bottoms from the cracked vapors.

The heavy oil is drawn from the bottom of the evaporator, and the vapors pass from the top of the fractionating tower. Fractionation by means of a bubble tower is obtained in the same manner as in crude-oil distillation. Cracked gasoline is taken "overhead" as a vapor, and one or more side streams are removed farther down the tower. These side streams usually are recracked by returning them to the original cracking still, or to a second cracking still operating at a higher temperature than the first because the products in the side streams are more refractory than the uncracked charging stock. The bottoms from the tower may also be recracked or recovered as fuel oil.

The operating procedures previously described should be regarded merely as typical examples, because modern refinery practice is subject to innumerable variations depending on the type of crude oil or cracking stock treated, the type of process used, the products desired, and other factors.

Introduction of the plate-and-bubble-cap type of fractionating tower or column into the petroleum industry represented considerable advance in consolidation of equipment, for it allowed several products to be separated in one column. It has virtually replaced the packed type previously employed for fractionation. The plate-and-bubble-cap column is a vertical cylindrical drum containing a series of horizontal plates or decks throughout its length. Each plate contains several caps with slotted edges inverted over short tubes leading through the plate and also has one or more drain tubes extending from a short distance above the plate down to the next lower plate. In operation, vapors pass up through the vapor tubes into the cap, where they are forced to pass through the slots in the caps. The latter are below the liquid level on the plate; consequently the vapors must bubble through the liquid to escape into the space above the plate. In so doing the vapors are scrubbed free of the heavier material, which condenses on the plate. The excess liquid flows down the drain tube to the next lower plate, and the scrubbed vapors pass to the next higher plate, where similar action occurs. In continuous operation with uniform charging stock and under fixed temperature conditions, the characteristics of the material on each individual plate remain almost constant, allowing removal of a desired product from the plate at which it occurs. In like manner, several different products may be removed continuously from one tower. For example, with crude oil as a charging stock to the pipe still, gasoline may be removed from the top of the bubble tower as a vapor, kerosene and gas oil as liquid side streams farther down the tower, and reduced crude oil as a liquid from the bottom of the tower.

Tube stills and bubble towers operating under vacuum have replaced to a great extent the steam reducing stills formerly used in the manufacture of lubricants and asphalts. By the newer methods much heavier lubricating-oil stocks of higher viscosity may be obtained and asphaltic crude oils reduced to much harder asphalts without endangering their quality by decomposition.

Another application of bubble towers is to "stabilize" refinery and natural gasoline to meet vapor-pressure requirements of commercial motor fuels. After some heating the gasoline is introduced into a tower, and the temperature at the top is controlled to allow most of the butane and all the propane and lighter gases to leave the tower as vapor. The remaining gasoline is withdrawn from the bottom of the tower; the actual top temperature depends on the pressure in the tower and the desired vapor pressure of the gasoline.

Distillation, fractionation, and cracking are the three basic "tools" of the refiner for separating and preparing virtually all stocks from which commercial petroleum products are made. Application of these three processes is subject to wide variation, but the principles remain the same.

The trend toward increased capacity and consolidation of parts is shown in the new so-called combination units, of which the most common combine crude distillation and cracking. "Re-forming" and "viscosity-breaking" sometimes are joined with other cracking operations. Combining equipment for several steps in refining into one unit has several advantages. The more important of these include the following:

(1) Waste heat from one step in the process may be utilized to provide necessary heat for a second step.

(2) Reduction of costs will result from decreased operating personnel requirements.

(3) Duplication of individual pieces of equipment may be avoided; for example, one furnace may serve several different heating requirements, and one bubble tower may be used to fractionate both straight-run and cracked gasoline.

Numerous automatic control devices are employed in modern petroleum refineries and have played important roles in refining development. They have done much to provide smoother operation of equipment and unvarying quality of products. These instruments control furnace, still, and tower temperatures; pressures in stills, towers, and other equipment; liquid levels; rates of flow for both liquids and gases; and charging and reflux pump rates. They may be used singly to control one operation, or in combination to provide interrelated control of several operations in a refining unit. Automatic-control instruments help to alleviate inaccuracies of manual control and reduce operating personnel requirements.

## RECENT DEVELOPMENTS IN PETROLEUM-REFINING TECHNOLOGY

From 1934 to the present, technologic advances in petroleum-refining methods have been rapid. Results of hydrocarbon-reaction studies, the commercial application of catalysis to hydrocarbon reactions together with better methods for chemical analysis, and increased efficiencies and better control of commercial refining processes have aided the recent major advances in petroleum-refining technology.

Although the industrial expansion of the petroleum industry has been tremendous since the beginning of the twentieth century, increased knowledge of the chemistry of petroleum did not pace engineering developments until about the past decade. Since that time, however, contributions to petroleum chemistry have been progressively more frequent and enlightening. During the past 5 years the results of these chemical studies have been manifested in the numerous petroleum-refining processes depending on hydrocarbon chemical reactions that have been introduced to the industry. These processes include catalytic cracking, polymerization, alkylation, hydrogenation, dehydrogenation, cyclization, aromatization, and isomerization, to be discussed in order.

*Catalytic cracking.*—This process is similar to thermal cracking in that larger quantities of better-quality gasoline are made from a variety of charging stocks than can be obtained by straight distillation of charging stocks. However, it differs from thermal cracking in several important respects. Materials called catalysts are important agencies of the process. Catalysis is defined in Webster's Unabridged dictionary as "acceleration of a reaction produced by a substance (called the catalyst) which may be recovered practically unchanged at the end of the reaction." Yields of 80 to 90 percent of motor fuel having an octane number of 80 and an octane blending value of 100 have been reported by operators using gas oil as a charging stock. Although maximum yields of high-octane motor fuel usually are desired, operating conditions may be controlled to produce high yields of light fuel oil from heavy stocks when there is a demand for this commodity. Catalytic cracking used by itself or in combination with thermal cracking and other refining processes offers great possibilities for aiding the conservation of petroleum resources because of its ability to convert poor-grade materials into first-class products. A. E. Pew, Jr., in a discussion of catalytic cracking by the Houdry process at the National Petroleum Association meeting, September 13–15, 1939, stated that catalytic cracking is limited only by the ability to vaporize material before it is brought into contact with the catalyst. He stated further that the bottom 30 percent of all the crude oil (the 30 percent of the crude oil with the lowest volatility) charged in the Sun Oil Co. Marcus Hook refinery is run to the catalytic cracking unit, recovering gasoline and gas oil.[6]

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[6] Pew, A. E., Jr., Oil and Gas Jour., vol. 38, No. 19, Sept. 21, 1939, p. 67; Nat. Petrol. News, Sept. 20, 1939, pp. R403, R404.

At the same meeting Arch L. Foster estimated the crude-oil capacity of catalytic cracking units in operation or under construction in the world at about 300,000 barrels a day. Three of the catalytic units included in the above estimate are in Europe.[7]

*Polymerization.*—The polymerization process of forming heavier molecules from lighter ones is the reverse of the type of chemical reaction obtained in cracking. The primary products of polymerization are called polymers, hence the term "poly" gasoline. The present commercial applications of the process utilize cracking-still gases (which formerly were used as refinery fuel or wasted) or natural gases, and both catalytic and thermal processes are in use. To cause gases or highly volatile liquids to combine by polymerization to form heavier products, they must have the chemical structure designated as unsaturation; that is, their molecules must contain a smaller number of hydrogen atoms than the complement corresponding to the number of carbon atoms in the molecule. Refinery cracking-still gases contain various proportions of molecules of this kind, called olefins, and polymerization proceeds directly if the charging stock to the "poly" plant is composed of refinery gases. However, natural gases are saturated (contain their complement of hydrogen atoms). Consequently, if it is desired to make polymers from constituents of natural gas (such as butane), the charge is subjected to a preliminary cracking step in the process to convert it as completely as practicable to the unsaturated state, after which polymerization proceeds as for refinery or cracking-still gases.

The starting materials for thermal polymerization may include any or all of the hydrocarbons having three or four carbon atoms. The reaction is complex, and its exact mechanism is not known. The charging stock is subjected to high temperature and pressure for a period long enough to give satisfactory conversion but insufficient to cause an excessive amount of coking in the equipment. Under these conditions a mixture of hydrocarbons having five or more carbon atoms is formed, which are separated by distillation from hydrocarbons of lower molecular weight. The product is used in motor gasoline, where it is desirable because of its high octane value and good volatility with low vapor pressure.

Catalytic polymerization operates under mild heat and pressure, with a solid catalyst to produce a controlled liquid product boiling within the gasoline range. The gasoline formed consists of relatively few hydrocarbons, which when stabilized yield a high-octane-value motor fuel of high volatility and low vapor pressure.

A few years ago isooctane for use as a reference fuel for determining the octane rating of gasoline was a rare chemical and sold for $20 to $25 per gallon. The first commercial quantities of isooctane were manufactured in 1934; by 1935 this commodity was being made in larger quantities for direct use in aviation fuel and sold for less than 40 cents per gallon. Since then the process has been developed further, and much larger quantities of high-octane material are available for blending into aviation fuel.

Egloff states: "Over nine billion gallons of polymer gasoline may be produced yearly from hydrocarbon gases produced in the United States, of which over one billion gallons may be isooctane fuel of 95 to 100 octane rating."[8] Polymerization units having a combined capacity of well over 100 million cubic feet per day are now in operation. No specific data as to the yields from these plants are available.

Although polymerization is applied principally to the manufacture of fuels, it is also used (sometimes in combination with other processes) in the manufacture of synthetic resins, plastics, rubber, and similar materials and lubricants.

*Alkylation.*—This process is somewhat similar to polymerization, except that unsaturated and saturated isohydrocarbons are joined directly in a one-step operation to produce a branched-chain saturated hydrocarbon of high antiknock quality. For example, butylene (unsaturated) may combine directly with isobutane (saturated) under proper operating conditions to produce isooctane (saturated), which has an octane number of 100. Both thermal and catalytic alkylation processes are now used commercially. Unsaturated gases or olefins are found in cracking still gases or may be produced by dehydrogenation of natural or refinery saturated gases. The saturated iso compounds are present

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[7] Foster, Arch L., Catalytic Cracking Assuming Major Importance: Oil and Gas Jour., vol. 38, No. 19, Sept. 21, 1939, p. 67; Nat. Petrol. News, Sept. 20, 1939, pp. R394–R398, R400, R403.

[8] Egloff, Gustav, Morrell, J. C., and Nelson, Edwin F., Motor Fuels from Polymerization: Oil and Gas Jour., Nov. 12, 1937, p. 176.

in refinery and natural gases or may be formed from normal saturated gases by isomerization, which will be described later.

Although alkylation processes for the manufacture of motor fuels use straight-chain hydrocarbons for base stocks, experimental results have proved that alkylation of naphthenes and aromatics is possible and in most instances practical. This information increases tremendously the possible scope of a synthetic chemical industry in which petroleum and hydrocarbon gases will be used as raw materials.

*Hydrogenation.*—The process of adding hydrogen to an unsaturated hydrocarbon molecule to produce a more highly saturated molecule is called hydrogenation. High pressures and temperatures and the aid of a catalyst are needed to produce the desired chemical reaction. Hydrogenation was one of the first catalytic processes to be adopted by the oil industry, as the first commercial plants in the United States were built 10 years ago. Since that time other plants have been constructed, the greatest increase coming within the last 5 years with introduction of those polymerization processes in which it is necessary to hydrogenate the polymer products to make commercial motor fuels. Hydrogenation is not confined to the manufacture of motor fuels, for the formation of saturated hydrocarbons from unsaturated ones is desirable in many phases of the petroleum-refining industry. Synthesis of high-quality lubricants and Diesel-engine fuels, and desulfurization of sulfur-bearing oils are only a few of the many additional applications of hydrogenation.

*Dehydrogenation.*—The chemical reaction that is the reverse of hydrogenation, known as dehydrogenation, is a process of recent development as regards the petroleum industry. Its first application was in re-forming gasoline, which, although commonly thought of as a cracking process, in reality is a form of thermal dehydrogenation. Commercial processes now in operation are both catalytic and thermal and are used principally to dehydrogenate saturated gaseous hydrocarbons to produce starting material for the alkylation processes.

*Cyclization.*—This is a process by which the molecular structure of straight-chain hydrocarbons is changed to a ring structure. For example, hexane (a straight-chain paraffin hydrocarbon—octane number of 40) by cyclization is changed to cyclohexane (a ring-structure naphthene hydrocarbon—octane number, 80) with the loss of one molecule of hydrogen. The antiknock values of naphthenes usually are appreciably higher than those of the corresponding straight-chain paraffin; thus the process may be used to improve the quality of low-value motor-fuel stocks. The process is also a stepping stone in the aromatization process described below.

*Aromatization.*—An additional step in the cyclization and dehydrogenation processes yielding aromatic compounds as the final product is called aromatization. For example, cyclohexane formed by cyclization (discussed in the previous paragraph) may be dehydrogenated further to produce benzene, an aromatic hydrocarbon. Aromatics usually have higher antiknock values than naththenes having the same number of carbon atoms. In the example, given under the discussion of cyclization, benzene with an octane number of about 100 is formed from cyclohexane, which has an octane number of 80. In addition to their value as motor fuels, aromatic compounds serve as the bases of such materials as dyestuffs, explosives, drugs, flavors, perfumes, photographic developers, synthetic resins, and plastics.

*Isomerization.*—A catalytic process of molecular rearrangement called isomerization is another important and effective method by which the refiner may change his products from what they are to what he wants. It differs from the processes previously described in that no change is made in the number of carbon or hydrogen atoms; it merely causes a shift or rearrangement of the atoms in the structure of the molecule. Compounds of identical molecular weight that contain the same chemical elements in the same proportions but have different molecular structure are called isomers. Isomerization may be used alone as a method for increasing the antiknock value of low-grade fuels or in combination with other processes, as in the preparation of starting materials for alkylation.

The isomerization process has progressed beyond the experimental stage, as at least one large commercial installation is now operating.

The foregoing processes are the outgrowth of the recent intensive studies of the chemical reactivity of hydrocarbon compounds found in petroleum. The impetus for these studies was due principally to the race for gasoline of higher and higher octane number to meet the requirements of modern airplane- and automobile-engine design. The fuel required, especially for airplane engines, could not be made by thermal cracking. Gasoline of 100-octane rating is desirable for military and commercial airplanes because of the increased power, speed, and load-carrying ability of engines designed to operate on this fuel. Tests have shown that 100-octane-number aviation fuels have made possible a 15- to 30-percent increase in power for take-off and climbing and a 20-percent reduction in cruising fuel consumption when compared to a previously available fuel of 87-octane number.[9] Higher-octane-number motor fuels will allow further increases in compression ratios of automobile engines which will in turn bring about greater flexibility of operation, increased power, and more miles per gallon.

All the new refining processes are aids to the progress of conservation of petroleum resources for they not only utilize inferior and oftentimes waste products to produce superior fuels, but the high quality of the fuels so produced permits greater mechanical efficiency in use, thus reducing the over-all raw-material requirements to generate each unit quantity of power.

## REMOVAL OF HYDROGEN SULFIDE FROM NATURAL AND REFINERY GASES

Many natural gases and most cracked gases from refineries contain hydrogen sulfide, a toxic gas with a disagreeable odor. Usually it is necessary to remove this impurity from these gases because municipal ordinances limit to small proportions the amount of hydrogen sulfide permitted in city gas.[10] The gas also causes corrosion in pipe lines and distributing systems and is a definite hazard to health because of its physiological effects. If the gases are used as feed for any of the various synthetic motor-fuel processes, hydrogen sulfide may "poison" the catalyst, thus causing a decrease in the efficiency of the process and corrosive and malodorous sulfur compounds, soluble in the motor fuel, may be formed.

Various commercial processes[11] for removing hydrogen sulfide from gases are in operation. Some of these include means for manufacture of sulfuric acid from the recovered hydrogen sulfide. In another type of process the sludge formed in the treatment of petroleum fractions with sulfuric acid, called "acid sludge," is burned in special equipment; and the sulfur dioxide formed as a result of combustion is converted to sulfuric acid by means of a catalyst, thus producing from an undesirable waste product a material useful to improvement of several petroleum products.

## RECOVERY OF GASOLINE FROM NATURAL AND REFINERY GASES

Natural gasoline, extracted from natural gas, in which it occurs as vapor at normal atmospheric temperature and pressure, comprised approximately 8.9 percent of the volume of motor fuel manufactured in the United States in 1938. Methods of extraction involve one or more of the following steps—compression of the natural gas as it comes from the well, refrigeration of the natural gas or the compressed gas, and either absorption of the liquid constituents of the natural gas in a heavy oil or adsorption on charcoal. The liquids subsequently are driven from the extracting mediums by heat and condensed to liquids again. Combinations of the methods may be used. A process placed in operation in 1938 in a plant at Benavides, Tex., does not use absorption but rather employs a combination of refrigeration and substantially complete dehydration of the gases. It is said to show high recovery and advantages of flexibility and simplicity of equipment and operation, as well as relatively low utility requirements.

Through improvements in methods of manufacturing the yield of natural gasoline per 1,000 cubic feet of gas processed continued to increase until 1929, when controlled stabilization for removal of the highly volatile fractions (propane and butane) was developed extensively. The yield then decreased until 1935, when it started to increase again, showing, in part, the results of using improved equipment and in part the increased application of gas from the East Texas district, which contains a relatively large proportion of natural gasoline constituents. A substantial portion of the volatile fractions, formerly lost by

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[9] Frolich, Per K. Chemical Trends in the Petroleum Industry: Ind. Eng. Chem., vol. 30, No. 8, August 1938, pp. 916–22.

[10] National Bureau of Standards, Standards for Gas Service: Circ. 405, 1934, 258 pp.

[11] Chemical and Metallurgical Engineering, Cleaning up Refinery Gases: Vol. 45, No. 8, August 1938, p. 416.

California Oil World, Removal of Hydrogen Sulfide and Carbon Dioxide from Natural Gas: Nov. 5, 1937, p. 29.

weathering, is utilized as liquefied petroleum gases. An outlet for these volatile fractions that is increasing in importance is the manufacture of high-antiknock gasoline by the polymerization, alkylation, and similar processes previously described.

Vapor is recovered in refineries by processes similar to those used in extracting natural gasoline from natural gas. All tanks, stills, and other equipment from which gas is evolved in volumes large enough to be of consequence, either from the standpoint of value or safety hazard, are made gas-tight and provided with outlets through which vapor-laden gases are conducted to a central gathering plant. This plant ordinarily is of the absorption type. The condensable vapors are extracted from the gas, stabilized, and blended with refinery gasoline stocks, or the desired portions are used as feed for polymerization, alkylation, and similar technique. The dry gases usually are burned as fuel in the refinery, although the gas from some favorably situated refineries, after suitable purification, is sold to public-service corporations for distribution as city gas.

## TREATMENT AND OTHER FINISHING PROCESSES

Commercial equipment and methods for separating crude oils and other natural and synthetic materials into fractions of the desired boiling range have been described so far in section III. The following discussion will be devoted to description of methods used to prepare these fractions further for commercial use.

*Gasoline.*—Almost all gasoline distillates require chemical treatment in addition to distillation, fractionation, and conversion processes to adapt them to commercial requirements. Sometimes minute quantities of impurities make the product unsuitable for use as a commodity. Moreover, chemical stabilization of some of the constituents is necessary to prevent formation of gums and other deleterious materials in storage and use.

The object of treating is to remove from raw distillate certain constituents—principally elementary sulfur and sulfur compounds—that would have a harmful influence on the utility of the products. Other harmful and undesirable components are (1) those that impart a disagreeable odor to the product, (2) those that would form soluble and insoluble gumming materials, and (3) those that are unstable under the conditions under which the product is to be used.

Although great improvements have been made in chemical treating, one major process is basically the same as that used in the early days of the industry to treat kerosene. Improved technique and mechanical equipment for this process—sulfuric-acid treating—have increased its efficiency and reduced treating losses. One of the greatest improvements has been the use of subatmospheric temperatures and the decrease and control of contact time. No other single process has been devised that would entirely supplant sulfuric-acid treatment as an agent for desulfurization.

The "doctor" (sodium plumbite) treatment developed early in the history of the petroleum industry is still employed to a considerable extent to neutralize the effect of malodorous sulfur compounds in gasoline. Recent experiments have shown that doctor treating of some gasoline distillates has decreased their tetraethyl-lead susceptibility: that is, more tetraethyl-lead is required to increase the antiknock value of the doctor-treated distillate than to produce the same antiknock increase in the untreated distillate. Experiments also showed that doctor sweetening removed certain natural inhibitors of the formation of gums from the gasoline. The results of these experiments, with other factors, led to the development of several other sweetening methods. Metallic salts (principally copper and zinc) are used in most of the new processes as sweetening agents. Sodium and calcium hypochlorite solutions have found especial favor in the natural-gasoline industry but have not proved very successful in treating cracked gasolines. Processes in which activated earths, such as fuller's earth, are used to remove gum-forming materials from gasoline, both in the liquid and vapor phase, are now employed to a considerable extent.

Present tendencies of the industry are (1) to add certain chemical compounds, known as "inhibitors" or "antioxidants," to the gasoline to prevent formation of excess gums and (2) to limit chemical treatment to that necessary to remove malodorous and corrosive sulfur compounds and reduce the sulfur content to trade standards.

*Kerosene.*—Kerosene distillates obtained by distillation and fractionation of crude oils usually require treatment to prepare them for commercial usage. Kerosene fractions from paraffin-base crude oils employed for the manufacture of range and illuminating oils ordinarily must be treated lightly with sulfuric acid to improve their color and burning qualities. Kerosene distillates from naphthene-base oils are extracted with liquid sulfur dioxide or some other solvents to separate undesirable constituents from desirable, and illuminating oil of good quality is produced. The extracted portion, although undesirable in burning oils, has been favored as a paint thinner, as a carrier for insect sprays, and for other uses.

Kerosene fractions used as fuels for domestic heating appliances and as tractor fuels seldom require additional treatment; however, specification requirements for these products may make necessary chemical treatment of these fractions from some crude oils.

*Gas oils.*—The major portion of gas-oil distillates is employed as charging stock to cracking units and requires no chemical treatment. Such treatment seldom is required for gas oils used as fuel for domestic and industrial heating, for gas making, as asphalt solvents, or as absorption oils in the natural-gasoline industry. However, for some special applications, such as fuel for high-speed Diesel engines, treatment of the material sometimes is required. The gas-oil fraction from paraffin-base and some intermediate-base crude oils make fuels of good ignition quality, but naphthene-base crude oils usually yield poor-quality fuel for high-speed Diesel engines. However, experiments have shown that solvent extraction of gas-oil fractions gave Diesel fuels of good ignition quality. Solvents, such as sulfur dioxide, having preferential solubility for naphthene and aromatic hydrocarbons, were used to remove these undesirable constituents from the gas oil.

*Lubricating oils.*—The greatest recent improvement in the manufacture of lubricating oils is application during the last 10 years of solvents or chemical reagents that dissolve selectively undesired constituents of the oil. The impetus for this development came from the demand of motorists for a lubricating oil whose viscosity will change as little as possible with temperature, so that it will be light enough to start easily on a cold morning but still retain enough viscosity at normal operating temperatures to protect the engine from undue wear and high oil consumption. Until the solvent refining processes were developed, the petroleum industry depended on the limited supplies of paraffin-base oils for its lubricants of high viscosity index. Since application of these processes was begun the situation has been completely changed, so that high-grade lubricating oils are now manufactured from petroleum stocks previously considered of inferior quality.

The following excerpt from an article by Poole [12] sets forth the basis for using solvents in petroleum refining:

"If two liquids are mixed together, it may be found that they become perfectly blended to form a single homogeneous liquid. This is what happens when gasoline and lubricating oil are mixed at room temperature.

"On the other hand, it may be found, upon mixing, that one liquid will settle to the bottom and the other rise to the top of the container. Having two clear substances in glass, like gasoline and water, the level where one stops and the other begins can be clearly seen. The above two substances appear to be essentially uncontaminated each by the other.

"The first case, that of complete miscibility has no value in the present discussion, other than that it is representative of inoperable and useless procedure:

"If, having an oil to be refined, a solvent is added to it, no refining action is possible if only a single phase results.

"The second case, that of essentially complete immiscibility, may in theory offer opportunity for refining action. Actually it, too, has as yet been found to have little practical significance other than to be representative of inoperable procedure; in that, if having an oil to be refined, and a solvent is added to it, no refining action is possible if neither substance dissolves the other.

"When two liquids are mixed there is only one possible happening which provides expectancy of refining action. Each of the two liquids must 'dissolve' to a limited but appreciable extent in the other, thereby to provide two separable phases; one which will consist predominantly of one of two substances, the other consisting predominantly of the remaining substance. To be sure, the system may or may not be suitable for commercial use, a matter dependent upon further restrictions.

"If two liquids are only partially miscible, they will of course—if mixed in certain proportions—form two separate and distinct phases.

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[12] Poole, John W., Modern Solvent Refining Theories and Practices: Oil and Gas Jour., vol. 35, No. 51, May 6, 1937, p. 59.

"Analysis of these phases will usually reveal that one phase is composed predominantly of one liquid and that the other phase is composed predominantly of the other liquid. Nevertheless each phase will be found to contain amounts of both of the two original liquid components."

On the basis of these principles solvents have been adapted to three types of lubricating-oil refining: Solvent dewaxing, solvent extracting processes by which the undesirable portions of the oil may be separated from the desirable, and deasphalting. Extraction methods have progressed from early single-stage contact in an agitator to present schemes of countercurrent treatment. Many different solvents are used, and research is being conducted constantly in an effort to improve solvent refining. The success of solvent refining methods is indicated by the fact that present plant capacity is large enough to process some 90 percent of the country's demand for lubricating oils.[13]

Blending small percentages of addition agents with lubricating oils to improve their quality has gained considerable momentum during the last few years. Brief descriptions of some of these agents and their effect on lubricants follow:

1. Low percentages of straight-chain materials of high molecular weight, formed by the polymerization of unsaturated gases, decrease the temperature susceptibility of lubricants considerably when blended with them.

Another group of synthetic materials, commonly called "pour-point depressants," are used to lower the pour point (the temperature just above that at which the oil congeals) of lubricants, thus reducing the amount of dewaxing necessary to produce low-pour-point lubricating oils. These "pour-point depressants" usually are high-molecular-weight condensation products of aromatic compounds and paraffin wax.

3. Other synthetic compounds, usually aromatic and sometimes containing combined nitrogen, phosphorus, or sulfur groups, have been developed as inhibitors to improve the high-temperature stability of lubricating oils and to reduce sludge formation, ring sticking, and bearing corrosion in modern engines.

4. Certain synthetic organic compounds are used to improve the "oiliness" characteristics of lubricants. These materials are blended with the lubricants in low concentrations, usually less than 1 percent.

5. Introduction of hypoid gears in automobiles necessitated development of extreme-pressure (E. P.) lubricants and greases. Lead soaps and chlorinated or sulfurized addition agents have met the demand for this type of material.

*Asphalts.*—Methods for manufacturing asphalt from crude petroleum have been developed rapidly in the last few years The earliest used was simple reduction with fire and steam in a batch still, but it is applicable only to heavy crude oils, such as certain heavy California and Mexican oils that contain large percentages of asphalt and some heavy crude oils found in Wyoming, Arkansas, Oklahoma, and Texas. Great care must be exercised to avoid local overheating.

The next step in developing asphalt manufacture was introduction of the continuous pipe-still method, in which the crude petroleum was pumped continuously through a pipe-still heater and then passed into a fractionating tower. The lighter ends were distilled off, and the heavy residual asphalt dropped to the bottom of the tower from which it was removed continuously. Blowing ordinarily is done at temperatures of 450° to 475° F., the exact temperature depending on the material being blown and the products desired. In general, blown asphalts are less susceptible to temperature changes and have greater elasticity and resilience than straight-reduced asphalts.

The most important step in manufacture of asphalts was development of the vacuum pipe still in which the lighter ends of the crude oil are first distilled off at atmospheric pressure, and the residual oil then is pumped through a secondary heater from which it passes into a fractionating tower maintained under high vacuum, usually 25 to 60 mm. mercury absolute. An uncracked asphalt of low penetration is formed.

Asphalts made in this way are called "reduced" petroleum asphalts. Reduced petroleum asphalt or liquid asphaltic material through which air has been blown while the material was at a high temperature is called "blown" or oxidized petroleum asphalt.

The materials termed "road oils" in the Bureau of Mines refinery statistics probably are preferably designated as "liquid asphaltic products." These are described as follows by the American Society for Testing Materials:[14]

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[13] Frolich, Per K., see footnote 9.

[14] American Society for Testing Materials, The Significance of Tests of Petroleum Products: Philadelphia, Pa., p. 70.

"LIQUID ASPHALTIC PRODUCTS

"(*a*) *Cut-back*—Petroleum asphalt fluxed with petroleum distillate.

"(*b*) *Residual.*—A liquid residual petroleum product produced by distillation, which may or may not be blended with other liquid petroleum products.

"(*c*) *Emulsified asphalt.*—A liquid mixture in which minute globules of asphalt are held in suspension in water or a water solution."

All three types of the liquid asphaltic products are in common use as binders for aggregates in the construction of low-cost, all-weather highways. Asphalts thinned with different solvents are also used for waterproofing and roofing paints and other similar uses.

Cut-back asphalts are prepared by diluting relatively hard asphalt with petroleum fractions such as gas oil, kerosene, or naphtha. Selection of the solvent to be used depends on the type of asphaltic product to be produced, such as medium or rapid "curing," and the type desired depends, in turn, on the manner and purpose of use.

As the names indicate, rapid-curing, cut-back asphalts require only a short time for the solvent to evaporate after the asphalt has been applied; consequently a low-boiling solvent, such as naphtha, is used. Medium-curing asphalts are cut back with a corresponding heavier distillate, such as kerosene. Several grades of both rapid- and medium-curing asphalt are manufactured.

Slow-curing asphalts usually are residual products that have not been cut back. These are made by reducing the crude oil or crude-oil residue to the desired consistency. Some slow-curing asphalts are cut-back products made by blending a hard asphalt with a gas-oil distillate. Several grades of slow-curing asphalts are manufactured, the extent of the reducing process depending on the specifications to be met.

Emulsified asphalts are asphalts or fluxes that have been emulsified with water. The asphalt-water emulsions are more fluid or mobile than the original asphalt; consequently they are easier to apply. Emulsified asphalts are used for cold-patching, road-laying, and a number of other special purposes. Use of emulsified asphalts is especially desirable where a fire hazard would be caused by use of cut-back asphalts containing volatile inflammable solvents. Such conditions exist in the construction of asphaltic types of floors in buildings.

## SECTION IV. SOME TECHNICAL FACTORS AFFECTING SUPPLY OF AND DEMAND FOR PETROLEUM PRODUCTS

The following pages present brief discussions of the influence of some technical factors that affect supply of and demand for gasoline and other products of petroleum refining. Comments also are given relating to possibilities of increasing supplies of products if demand should increase. The effect of the demand for several different uses of a given product on the supply for each use is pointed out. Significant changes in the demand for certain products are illustrated by statistics. Inasmuch as technical advancements in manufacturing methods have been discussed in section III this section will deal with changes in utilization of petroleum products that will have direct bearing on new or increased uses for products. The principal classes of petroleum products are discussed with regard to the purposes for which they are used and by whom they are used, as well as from the viewpoint of the purely technical factors involved in their manufacture and utilization.

### GASOLINE

During the past 25 years a great deal of thought and study has been devoted to technologic and economic factors that affect the supply of and demand for motor fuel. A voluminous literature has developed from discussion of these problems. A brief outline of some phases of the problem that affect the present situation follows:

*Bureau of Mines Gasoline Surveys.*—The question, "What is gasoline?", first became acute about 1914. During the first decade of the twentieth century the demand for gasoline was small and easily met. Early in the second decade demand began to catch up with available supply, with a resulting effect on quality. In 1915 the Federal Bureau of Mines made the first comprehensive survey of physical and chemical properties of gasoline sold throughout the United States. This survey was followed by similar surveys in 1917 and 1919 and by semiannual gasoline surveys from 1920 until, owing to lack of funds, they were dropped with the survey of August 1931.

The surveys were resumed, however, beginning with one for the winter of 1935–36, pursuant to a cooperative agreement between the Bureau of Mines and the Cooperative Fuel Research Committee. These surveys are the best available record of changes in properties of commercial gasoline sold to the general public.

### GASOLINE SPECIFICATIONS

In the earlier years of the petroleum industry in this country (until about 1910), gravity was almost the only specification for gasoline. This test was satisfactory when all known crude oils yielded about the same type of product. Since kerosene was the principal commodity, gasoline was not likely to contain material that should have been put into the kerosene portion. Later, the increasing use of automobiles caused a rapid growth in the demand for gasoline, and at the same time expanding use of gas and electricity for illumination and cooking retarded growth of the demand for kerosene. Although the total demand for kerosene did not decrease, a relative increase in the supply of that product resulted from the great increase in refining activities to meet the demand for gasoline.

The increased demand for gasoline made it profitable to mix kerosene or heavy naphtha with natural gasoline (a comparatively new product) to obtain a product equal in gravity to gasoline made in the regular way. Moreover, some of the newly discovered crude oils contained enough sulfur compounds to make it necessary to eliminate these substances from the finished product. For the above reasons distillation tests, sulfur limits, and corrosion tests became part of specifications, and these and other tests have supplanted the gravity test.

Present specifications for gasoline differ according to the type of service and the climatic conditions under which the fuel is to be used. Gasoline specifications usually embody some or all of the following items, which will be discussed in order: Corrosion test, distillation characteristics, vapor pressure, octane rating, sulfur content, and gum stability.

### EFFECT OF COMMERCIAL REQUIREMENTS ON AVAILABLE SUPPLY OF GASOLINE

In connection with discussion of the several items of gasoline specifications mentioned in the preceding paragraph, consideration will be given to the effect of specifications and trade standards in limiting and determining the quantity of gasoline that can be made from a given quantity of raw material. The question of how much more gasoline could be made if certain test requirements now in vogue could be relaxed or eliminated is worthy of consideration because technologic developments may permit the specifications to be made less stringent.

*Corrosion test.*—This test involves determination of the discoloration produced when a strip of sheet copper is immersed in the gasoline for 3 hours at 122° F. (50° C.). Although the test is a delicate one and will disclose the presence of an extremely small proportion of elementary sulfur or other corrosive sulfur compound, it does not appear to have a decidedly adverse effect upon the available supply of gasoline. The reason is that almost all refiners have means of correcting corrosive properties at relatively slight cost and with small reduction in volume of gasoline. Moreover, available evidence indicates that, even if fuel tanks and fuel-feed systems of automobiles should be constructed entirely of corrosion-resistant material it would be desirable to process gasoline to pass the corrosion test because of the influence of that processing on other characteristics, such as gum-forming tendencies and odor.

*Distillation range.*—This item in specifications and trade standards probably is of greatest importance in restricting the quantity of material a refiner can include in gasoline. In the form in which the distillation range of gasoline usually is stated limits are set upon the quantity that must be evaporated when certain stated temperatures are reached in a distillation test standardized by the American Society for Testing Materials. For example, present gasoline specifications provide that not less than 10 percent of a gasoline shall be evaporated when the mercury of the thermometer in the distillation flask reaches a stated temperature point. Since this statement of limitation on the lower (volatile) end of the distillation range does not specify a maximum it may appear that it does not restrict the quantity of highly volatile material that may be included in gasoline. However, the maximum is limited by the vapor-pressure requirement.

The possibility of increasing the available supply of gasoline by increasing the distillation range at the upper (high-temperature) end can be illustrated approximately by the following considerations:

The Federal specification for motor fuel[15] permits a maximum temperature of 356° F. when 90 percent of the sample has been evaporated. The tentative specification for gasoline of the American Society for Testing Materials[16] provides for a maximum "90-percent point" of 392° F.

Almost all the gasoline now being sold to the general public is well within these limits. (See figs. 1 and 2.) If refiners should manufacture gasoline just to meet these specifications they could make a larger quantity of gasoline from the same amount of crude oil than they now are producing. If developments in automobile engines would permit raising the 90-percent point to a higher temperature refiners could make still more gasoline from the same quantity of crude oil. Production of gasoline could be increased markedly with only a slightly wider distillation range than the limits of present specifications.

*Vapor pressure.*—Bridgeman and Aldrich,[17] National Bureau of Standards, state the significance of vapor pressure of gasoline as follows:

"The vapor pressure of a motor fuel, as determined by the Reid method, is related to the readiness with which the fuel will start to ignite in the engine, and to the tendency to 'vapor lock' or form gas bubbles in the fuel feed of the automobile, which prevents the flow of fuel from the tank to the carburetor."

This item in gasoline specifications is a limitation placed upon the pressure generated when a stated quantity of gasoline in a specified metal container equipped with a pressure gage is immersed in water at 100° F. The maximum vapor pressure permitted by the Federal specification for Motor Fuel V is 10 pounds per square inch. The A. S. T. M. tentative specification permits a maximum vapor pressure of 13.5 pounds during winter months. However, only a small number of gasolines have vapor pressures as high as 12 pounds per square inch, even in winter in Northern States. Vapor-pressure requirements and octane rating are the principal factors that influence refinery operations in gasoline manufacture. Much controversy has been current among automobile engineers and petroleum technologists regarding permissible vapor pressures of gasoline for automobiles now in service.

From the standpoint of gasoline supply the significance of vapor-pressure limitations is that they restrict the quantity of volatile liquid (butane) that can be included in gasoline. Petroleum refiners have access to a great deal more butane than they can include in gasoline with present limitations on vapor pressure, for this volatile hydrocarbon is a constituent of crude oil, natural gas from which natural gasoline is made, and gases collected by vapor-recovery systems in refineries. There is no disagreement with the statement that butane is a highly desirable motor fuel, except that the quantity usable is limited by a tendency to "vapor lock" in the fuel-supply systems of present automobiles. Because of its volatility only a minor fraction of the total available supply can be used. The remainder must be disposed of in other ways, as, for example, in liquefied petroleum gases and manufacture of liquid products by polymerization. (See sec. III.)

*Octane rating.*—Octane rating is a measure of the tendency of a motor fuel to detonate or "knock" in the engine when a load is applied, as in ascending a hill or in accelerating after idling. Most of the straight-run gasoline obtainable from petroleum produced in the United States has too great a tendency to knock to be satisfactory to the average motorist of today and can be sold to the general public only at the lowest prices. Three means of correcting this condition are available:

(1) Straight-run gasoline can be cracked or "re-formed" (see sec. III) to improve its octane rating. Although re-forming increases the octane rating, loss of approximately 15 percent of the gasoline charged to the cracking plant is incurred.

(2) Straight-run gasoline can be blended with sufficient cracked gasoline, "poly" gasoline, or benzol to raise the octane rating of the mixture enough to meet commercial requirements. To produce gasoline with a high octane rating by cracking, the cracking must be more severe than would be necessary to produce gasoline with a lower octane rating. This more severe cracking entails greater loss of product, owing to decomposition into gas, coke, and liquid products such as butane too volatile to be used in gasoline with present limitations on vapor pressure.

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[15] Procurement Division, Treasury Department, Federal Specification for Motor Fuel V. Designation: VV–M–571a: Washington, D. C.

[16] American Society for Testing Materials, Tentative Specification for Gasoline; A. S. T. M. Designation D439–37T; Proc., vol. 37, pt. 1, pp. 872–74.

[17] Bridgeman, O. C., and Aldrich, E. W., Properties of Gasoline with Reference to Vapor Lock: Jour. Soc. Automotive Eng., vol. 27, 1930, p. 93.

"Poly" gasoline, made by polymerizing gases or highly volatile liquids to form materials in the gasoline range of volatility, is a promising means of improving octane rating that employs materials formerly used as plant fuel or wasted.

If more benzol than the present supply of about 0.3 percent of total motor-fuel demand should become available, the octane rating of a corresponding volume of straight-run gasoline could be raised without the loss of volume incurred in "re-forming." Under present conditions this eventuality is tied up with increased production of coal coke in ovens from which byproducts are recovered, which depends on activity in the steel industry.

(3) Tetraethyl lead can be added to increase the octane rating. This proprietary compound can be used to raise the octane rating of most straight-run gasoline and all cracked gasoline to meet present standards without reduction of volume. If economic conditions should permit, tetraethyl lead appears to be an available means of augmenting our gasoline supply without requiring additional crude oil.

The practical effect of octane rating on gasoline supply is that emphasis on high octane rating encourages severe cracking, in which costs of operation and maintenance of cracking equipment are high and yields are low. Less severe cracking produces higher yields of gasoline with lower octane rating, which is offset to some extent by the fact that gasoline with high octane rating used in an engine designed to take advantage of it yields more power per gallon of gasoline.

It is rather difficult to evaluate in definite terms the influence of present emphasis on high octane rating in restricting the available supply of gasoline. Data are not complete regarding the volume of losses incurred in reforming straight-run gasoline, and in cracking to produce high-octane gasoline versus low-octane gasoline, as well as regarding the extent to which present automobile engines can take advantage of possible benefits of high-octane gasoline in increasing mileage per gallon of fuel. However, future developments may be expected to provide means for improving the situation regarding the octane rating of gasoline. This may be expected to improve the motor-fuel situation by increasing the efficiency of utilization, if not the actual volume produced.

*Sulfur content.*—For the past 15 years Federal specifications for gasoline have contained a limitation of 0.10 percent on sulfur content. Commercial requirements limiting sulfur content were in effect in various parts of the country before that time. Laws of several States and trade standards in most localities in the United States now contain this limitation on sulfur content of gasoline. It is based upon the harm that may be done to the engine by corrosive products formed by oxidation of sulfur when the fuel is burned.

The influence of this limitation in permissible sulfur content on the available supply of gasoline cannot be determined definitely. There can be little doubt that in the process of reducing sulfur content some material is destroyed insofar as its use as motor fuel is concerned. Opinions regarding the extent of this loss differ. Data in the literature concerning the effect of treating raw gasoline with sulfuric acid to reduce sulfur content appear to prove that octane rating is reduced thereby. On the other hand, the effectiveness of tetraethyl lead in raising octane rating is increased by reducing sulfur content.

Probably the principal effect of limitation of sulfur content on supply of motor fuel is in reducing the quantity of raw material economically available. If the permissible sulfur content of gasoline were increased, not only would certain crude oils whose gasoline fractions have sulfur content higher than 0.10 percent attain a higher market value, but cracking of certain stocks not economically usable for that purpose under present conditions would produce gasoline of good quality, except for sulfur content.

In some areas of the United States, notably in the Pacific coast marketing area, gasolines with sulfur content well above 0.10 percent have been widely sold for many years. Apparently there has been no exceptional corrosion trouble in the region where these gasolines have been sold. However, the information available is negative rather than positive on this point.

The problem of sulfur removal has not been acute in the recent past, except possibly in a few districts. If in future it is found that (owing to changes in engine design and operating conditions) the present limitation on sulfur content of gasoline can be relaxed or eliminated, additional gasoline will result from elimination of treating losses and from the use of cracking material that cannot be used economically to manufacture gasoline under present conditions.

*Gum stability.*—Some straight-run distillates and most distillates made by cracking contain materials that form, in storage or within the automobile engine, soluble and insoluble materials called gums. Gum formation is related to the method of manufacture of gasoline. Available information indicates that trouble due to gum in gasoline is not extensive at present, although there is no doubt that when gum formation occurs it can cause serious trouble. On this subject the American Society for Testing Materials says:

"Excessive gum content in gasoline is attended by stickiness of the valve stems and carburetor mechanism, clogging of screens and filters in the fuel lines and formation of deposits in the intake manifold. All of these effects are reflected in uncertain engine performance.

"Certain metals, notably copper and brass, and other materials, such as solder flux, have an accelerating effect on gum formation." [18]

Trade standards require that gum formation be eliminated or reduced to harmless proportions. This can be done by treatment that removes the gum-forming constituents or by adding small amounts of chemicals called "inhibitors" that prevent the formation of gums. Treatment to remove gum-forming constituents has the disadvantage of removing constituents that have high octane rating, and the result is a smaller volume of gasoline with a lower octane rating. Inhibitors do not reduce the volume of gasoline, but they are not yet developed to the point where they afford complete assurance of absence of trouble from gum formation.

Technologic improvements may remedy the situation from two angles of approach: (1) More reliable inhibitors and better treating methods may be developed or (2) engine design may be improved to the extent that dissolved gums will not cause sticking of valve stems and other parts of engines.

The effect of the necessity for gum stability in restricting the supply of gasoline and increasing the cost of production is uncertain. However, there can be little doubt that chemical treatment to increase gum stability adds to cost and reduces the volume of product. Moreover, use of certain types of cracking processes that otherwise are satisfactory probably is deterred because they yield gasoline with poor gum stability.

### COMPARISON OF MOTOR-GASOLINE SURVEY DATA

As has been stated, the Bureau of Mines gasoline surveys were suspended after the results of the survey of August 1931 were published. Need for current data of the kind contained in that survey soon became evident, and representatives of the automotive and petroleum industries through the Cooperative Fuel Research Committee proposed to the Bureau of Mines a method of compiling gasoline surveys according to a plan somewhat different from the method of those issued previously. This procedure would be less costly to the Bureau and could be conducted within its restricted appropriations. The basis of the new proposal was that various oil companies throughout the United States make periodic surveys of motor fuels sold in the areas in which their own products are distributed. These company surveys contain data from tests of the same type that had been reported in Bureau of Mines gasoline surveys. It was thought that these company surveys might give a more intensive coverage of the gasolines sold in a given city because each company would be in a position to analyze a greater number of brands of gasoline in the cities in which it was interested as a marketer. Therefore, the suggestion was made that the companies supply data to the Bureau of Mines from their reports on samples from various cities so that the Bureau could compile surveys without incurring the expense and loss of time involved in taking samples throughout the United States and analyzing them in its laboratories. The Cooperative Fuel Research Committee acted as the coordinating agency for the companies under this plan.

The Cooperative Fuel Research Committee was organized in 1921 as a joint project of the National Automobile Chamber of Commerce (now the Automobile Manufacturers Association), the American Petroleum Institute, the Society of Automotive Engineers, and the National Bureau of Standards to study problems involved in mutual adaptation of the fuel and the engine to each other to the end of national economy and internal-combustion-engine efficiency.[19]

In 1935 the committee proposed that the Bureau of Mines compile, tabulate, analyze, and comment upon data furnished by individual companies and publish a report of the study for free distribution. After studying all of the consider-

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[18] American Society for Testing Materials: The Significance of Tests of Petroleum Products, Philadelphia, Pa., p. 30.

[19] Dickinson, H. C., The Cooperative Fuel Research and Its Results: Jour. Soc. Automotive Eng., August 1929.

ations involved, the Bureau assented to this proposal; a cooperative agreement was signed by representatives of both parties, and has been renewed annually.

Figures 1 and 2 are plots of averages of data from the seven semi-annual gasoline surveys made since 1935 under these cooperative agreements. To reduce the vertical height of figures 1 and 2 an interval equivalent to 50° F. has been indicated between the graphs for temperatures at which 10 percent and 50 percent were recovered in the distillation of gasoline and a similar interval of 50° F. between the graphs of temperatures at which 50 percent and 90 percent were recovered in the distillation. Thus the actual temperature difference between 10 percent recovered and 50 percent recovered, and between 50 percent recovered and 90 percent recovered is 50° greater than is indicated by the vertical

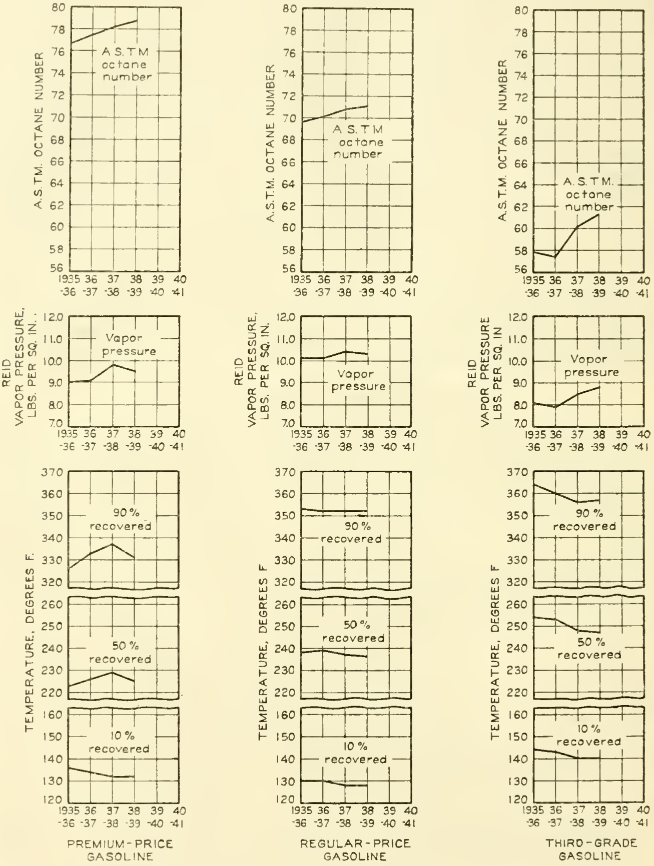

FIGURE 1.- COMPARISON OF GASOLINE CHARACTERISTICS FROM WINTER SURVEYS OF 1935-36 THROUGH 1938-39.

distance between the graphs. However, the graphs for each of these characteristics have been plotted on the same coordinates for each of the three groups of gasoline and, therefore, are comparable.

The graphs indicate that motor gasolines sold to the general public at service stations throughout the United States in the three principal price classifications fall into definite groups with respect to the characteristics reported in the surveys.

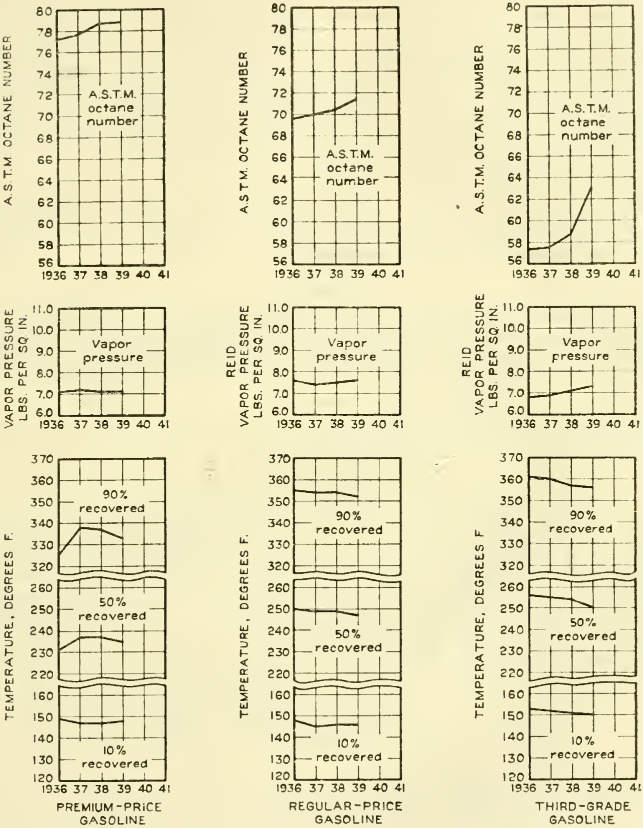

FIGURE 2.- COMPARISON OF GASOLINE CHARACTERISTICS FROM SUMMER SURVEYS 1936 THROUGH 1939

### RECENT CHANGES IN SOURCES AND USES OF GASOLINE

The most marked change in demand for gasoline during the 5-year period, 1934–38, has been the increased demand for fuel for motortrucks and busses and for aviation. Although busses and trucks powered with Diesel engines and engines using propane, butane, and propane-butane mixtures as fuel have increased in number and in installed horsepower, the aggregate demand for fuel for these vehicles is small compared with the use of gasoline in trucks and busses. The most important technologic changes in motor-gasoline properties and utilization since 1933 have been the increased octane number of gasoline and average horsepower of automotive vehicles.

Great progress was made during the 5-year period 1934–38 in the manufacture of synthetic gasoline by cracking—that is, formation of more volatile compounds of lower molecular weight from heavier oils—and by methods that employ the reverse procedure of making compounds in the gasoline range of volatility from materials that are gaseous at average atmospheric temperatures. Extension of the cracking process by catalytic cracking and development of the variety of other new processes for manufacturing gasoline that are discussed in section III of this report have done much to add to the raw material available for gasoline manufacture. For example, until recently, aviation gasoline was entirely a straight-run product, to which tetraethyl lead usually was added to reduce the tendency to knock in the engine. No cracked or synthetic motor fuel was used in aviation gasoline. Recently synthetic gasoline made by new processes has become an important factor in supplying increased demands for aviation gasoline of high octane rating.

Additional gasoline doubtless could be supplied by cracking a larger proportion of crude oil run to stills. How far this could be carried before the law of diminishing returns began to exert its effect would depend on such factors as the relative price of gasoline and cracking stock, including crude oil, as well as prices obtainable for other products.

## SUMMARY

The foregoing pages of this section present a brief review of the effect of technical requirements that restrict supply of gasoline, with suggestions regarding the possibilities of increasing supply by relaxing or eliminating present restrictive requirements as changes in engine design and other factors remove the necessity for retaining them.

Gasoline is a petroleum product that presents a many-sided picture of technologic factors affecting available supply. The story of kerosene, the next commodity to be discussed, is simpler.

## KEROSENE AND RANGE OIL

The demand for kerosene in the United States has been growing in recent years. Despite the high demand, however, available data regarding the details of its distribution among users are not conclusive, and the following discussion is based largely upon inference. The increased demand usually is ascribed partly to the large number of range-oil burners in use. This significant development of the last few years is due to conversion of many coal- or wood-burning cooking and heating ranges in household kitchens to use of oil as fuel. A large number of new installations also have been made for space and water heating, as well as for cooking. These units formerly were called "range-oil burners," from their use in kitchen ranges. Since these burners have been adopted for space and water heating they are now designated "distillate-oil burners" by the Bureau of the Census, apparently to make a distinction in name between them and domestic oil burners, which also burn distillate oil fuel. However, for the purposes of this report it seems preferable to preserve the distinction between range oil and distillate fuel oils, since the latter is used mainly for central heating in residences.

The technologic factors affecting the supply of fuel for range-oil burners apparently arise mainly in cost of manufacture and distribution. The large proportion of kerosene reported as being sold as range oil indicates that an oil meeting the requirements for kerosene as an illuminating oil is adequate for use in range burners. However, there appears to be some doubt that the careful selection of crude oil and the degree of refining required for manufacture of kerosene are needed to provide efficient fuel for range-oil burners. Refining beyond that necessary to provide a satisfactory product places a burden on a commodity used largely by the low-income group of householders.

However, the marketing problem also enters. Kerosene probably is used for lighting and for fuel in the same localities, and since individual demands (unit sales) for each purpose probably do not justify keeping separate stocks, for example, in neighborhood food stores, the major portion of the demand for range oil probably will be supplied by kerosene for some time to come.

Apparently electricity and gas have not displaced kerosene entirely as an illuminant, leading to the conclusion that the demand for kerosene for this purpose will continue for several years. Increased availability and lower cost of electricity and gas would tend to reduce the demand for kerosene; nevertheless, it is unlikely that annual consumption will fall below 50 million barrels during the next 5 years.

Aside from its use in wick burners for illumination, cooking, and heating, kerosene is employed as fuel in tractors and stationary engines, as a vehicle for insecticides, for cleaning mechanical equipment, and for a variety of other purposes.

The basic qualifications for kerosene are that it shall not be so volatile as to constitute a fire hazard and shall burn freely and steadily in a wick lamp, with as much freedom as possible from odor, smoke, and incrustation of the wick and chimney. The manufacture of kerosene to meet these conditions involves careful selection of raw material and skillful treatment. However, these limitations are not so severe as to cause a marked reduction in supply, and a considerably greater demand than has existed in the past undoubtedly could be met with little alteration in refinery practices. Although there have been slight changes in the various districts since 1933, the percentage yields of kerosene reported by the Bureau of Mines for 1938 are similar to those reported for 1933 and indicate that in most districts only a relatively small proportion of the available kerosene content of the crude oil is being refined. Most of the available supply has been going into cracking stock and light fuel oils.

The conclusion appears fully justified that no fear need be felt regarding availability of an ample supply of kerosene as long as crude-oil production continues at present levels and of equal quality. Whatever increase may occur in the demand for kerosene will reduce by the same volume the available charging stock for the manufacture of gasoline. Kerosene or kerosene distillate can be cracked to yield approximately 75 percent gasoline, 15 percent liquid residue, and 10 percent gas and loss.

### GAS OIL

Gas oil is that distillate with a distillation range higher than kerosene and lower than lubricating oil. In addition, it may invade the distillation range in which kerosene occurs and on the heavy end may include the lighter lubricating oils, such as spindle oils, when there is not enough demand for them. The term is both generic and specific and is better suited for use by petroleum refiners than for application to the commercial products that fall within the scope of its generic definition.

The gas oils illustrate in a different way than does gasoline how various factors influence supply and demand for petroleum products. Discussion of technologic factors that affect the supply of gasoline illustrated how technologic requirements restrict it and showed that it could be increased markedly without requiring additional crude oil or new refining equipment or methods.

Gasoline is used almost entirely for one purpose, namely, to propel automotive equipment. Conversely, the class of oil designated in refineries as gas oil has several uses, principally:

(1) For cracking to make gasoline.
(2) As fuel for domestic and industrial heating.
(3) As fuel for internal-combustion engines.
(4) For gas-making, from which gas oil gets its name.
(5) As solvent for asphalts.
(6) As absorption oil in the natural gasoline industry.

The chief factor affecting the demand for gas oil as a whole and the supply for a given purpose is the proportion of the total available supply that has properties fitting it for specific uses.

### FOR CRACKING

The cracking process probably will continue to demand the major portion of the supply of gas oil as long as demand for gasoline continues at present levels. Cracking plants apparently are the least selective of any of the present channels of consumption of gas oil, so that such oils unsatisfactory for other purposes can be cracked. Therefore, gas oil for uses other than cracking cannot be inexpensive if gasoline commands a high price. A general statement may be made that the more naphthenic gas oils produce cracked gasoline with higher octane rating than that formed from paraffinic type gas oil.

### AS FUEL FOR DOMESTIC AND INDUSTRIAL HEATING

The use of distillate fuel oil for heating homes has grown from an insignificant channel of consumption a few years ago into a market of real importance, and is now one of the most widespread applications of oil fuel. Distillate fuels have been employed for industrial heating for a much longer time.

*Domestic heating oils.*—Domestic oil burners may be defined generally as automatic or semiautomatic devices for space heating by burning oil continuously or intermittently to maintain a predetermined temperature. Automatic apparatus also is used to heat homes with coal and with gas. The number of automatic home-heating apparatus in use is small compared with the number of individual homes that may be emancipated from the labor and inconvenience of old-fashioned heating methods and a large field for sales remains. Whether these homes will be heated with gaseous, liquid, or solid fuels remains to be seen and will depend in large measure on the relative availability and cost of the three types of fuels and on progress in developing trouble-free methods of utilizing the fuels in that way.

Van Covern[20] has reviewed the statistics dealing with use of automatic home-heating apparatus. He says:

"Three times as many American home owners—2,898,473 against 868,100—now have automatic central-heating-plant equipment—oil burners, coal stokers, and gas heaters—as had automatic heat in 1930. At the end of 1938, however, only 57 percent of the automatic-heating equipment was oil-burning—although, in 1930, 77 percent used oil. The automatic coal stoker has made the most vigorous competitive inroads to reduce the lead of oil. In the 8 years since 1930 the number of domestic oil burners in use has increased 149 percent; the number of operating domestic stokers, however, has grown 2,600 percent. Gas-heater installations also increased more rapidly than oil burners in the first 3 years after 1930, but since 1933 the gains of oil and gas have been made at about the same rate.

"At the end of 1938 there were in operation 1,657,942 domestic oil burners, 414,531 mechanical coal stokers, and 826,000 automatic gas heaters. Comparable figures for 1930 are 665,100 units burning oil, 15,000 burning coal, and 188,000 burning gas. An analysis of operation data would show that the coal stoker constantly and remarkably has improved its relative position to the oil burner over the 9-year period, whereas the relationship of the gas heater to the oil burner has improved noticeably, but with a firm tendency toward stability."

Various types of domestic oil burners require fuels ranging in volatility and viscosity from kerosene to heavy gas oil; a small number of burners can burn oil containing a low proportion of residue. Commercial standards for fuel oils[21] have been adopted by burner manufacturers and petroleum refiners, and troubles formerly experienced owing to variations in characteristics of fuel oils have been greatly reduced. A commercial standard for domestic oil burners will become effective November 1, 1939.[22]

Apparently domestic oil burners are not greatly restrictive regarding the chemical characteristics of fuels. However, fuels suitable for oil burners also are suitable for other purposes, and the demand for oil for these other purposes will tend to increase the price of oil for domestic heating. During the past 5 years these factors have not been noticeably active in affecting the price of fuel oil because there has been a plentiful supply of oil for all purposes. Under the influence of increased demand for products and decreased supply of crude oil, growing demands for gasoline, Diesel fuel, kerosene, and other possible channels of consumption for that portion of the supply of petroleum products that is suitable for use in domestic oil burners may increase the price of fuel for these burners. However, this increase in price probably will not be out of line with increases in the prices of the alternative products and of prices generally. The most promising field of improvement in availability and cost of fuel oil

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[20] van Covern, Fred, Oil-Burner Lead in Home Heating Cut by Stoker, Gas Competition: Am. Petrol. Inst. Quarterly, vol. 9, No. 4, October 1939, pp. 21, 27.

[21] Fuel Oils, Commercial Standard CS12–39, published by the National Bureau of Standards; sold by Superintendent of Documents, Washington, D. C., 5 cents. See also American Society for Testing Materials, Tentative Specifications for Fuel Oils; A. S. T. M. Designation D396–39T: Philadelphia, Pa.

[22] National Bureau of Standards, Automatic Mechanical Draft Oil Burners Designed for Domestic Installations; Commercial Standard CS75–39: Washington, D. C.

appears to be in reducing the number of grades required and progress has been made in this direction.

The cost of domestic fuel oil in future will depend on the value of the fuel as cracking stock to produce gasoline and on demands from other sources. Oil for domestic heating must meet the competition of natural gas on the basis of convenience, and of solid fuels on the basis of cost. Smokeless fuels and automatic stokers may reduce the present handicaps of solid fuels for domestic use and check the trend toward oil and gas.

*Industrial heating oils.*—Fuel oils have been used in industry for direct heating for many years. The demand for fuel oil for this purpose varies with industrial activity and the price of oil relative to all alternative fuels. However, for some industrial applications a liquid or gaseous fuel is almost indispensable and is in demand because of its inherent advantages despite higher cost. For certain purposes, such as heat treating, ceramic furnaces, and heating nonferrous alloys, fuel with low sulfur content is required. For some purposes, particularly for brass furnaces, salt must be absent from the fuel. For other industrial purposes oil is used because of its greater convenience and lower net cost than alternative sources of heat.

### AS FUEL FOR INTERNAL-COMBUSTION ENGINES

In recent years there has been a great revival of interest in Diesel-type internal-combustion engines in the United States and in foreign countries, particularly in the development of high-speed Diesel-type engines for automotive transport, both rail and highway, and to a smaller extent for aircraft.

Since the Diesel engine was patented by Rudolph Diesel, of Munich, Germany, in 1892 it has evolved into many variations for different types of service. These include "semi-Diesel" engines and those in which the fuel is ignited by an electric spark plug instead of by spontaneous combustion due to the temperature of compression in the engine cylinder. Throughout the range of sizes and types, with various engine speeds and classes of service, these engines differ in fuel-oil requirements for satisfactory performance. This problem has been discussed extensively in the technical press of the United States and in foreign countries in recent years and has been investigated intensively by petroleum refiners, engine manufacturers, and users.

The principal interest in oil-injection engines has been the question of whether the high-speed engines in this class will become important factors in transportation by private passenger automobiles, busses, trucks, railway locomotives, and aircraft. Apparently the most successful adaptation in the United States thus far has been in locomotives for high-speed passenger trains on main lines and for branch-line passenger and freight service. Some time must elapse before it will be decided definitely whether this departure from conventional railroad practice will increase in importance or will remain a comparatively small item. Possibly its chief appeal up to the present has been its novelty and the sustained high speeds attained by streamlined passenger trains. In addition, Diesel-engined locomotives have appealed to railway executives because they appear to be a promising means of reducing costs of moving passengers and freight. Ralph Budd, president of the Burlington Lines, is quoted by Norman[23] as follows:

"The cost per train-mile for locomotive maintenance, locomotive fuel, and lubricating oil on the four smaller Zephyrs (3 and 4 cars each) has been an average of 4.84 cents. The cost per locomotive-mile for steam-drawn trains of the same carrying capacity has been 28.98 cents. For the larger trains comparisons are more difficult because we have no similar steam schedules."

### FACTORS THAT MAY AFFECT DEMAND FOR GAS OIL AS DIESEL FUEL

*Suitability of Diesel-type engines for automotive service and possibility of overcoming shortcomings of present Diesel-type engines as to operating characteristics and fuel tolerance.*—Diesel engines are sensitive as to the type of fuel they will burn satisfactorily. High-speed Diesel engines, which are intended for use under conditions of suddenly varied speed and load, are markedly more sensitive than the slow-speed Diesel engines used in stationary service under relatively constant conditions of speed and load. Additional information is

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[23] Norman, H. Stanley, Improved Gasoline and Oil: Diesel Fuel Demand to Expand: Oil and Gas Jour., vol. 36, No. 25, Nov. 4, 1937, pp. 9–10.

needed regarding the essentials of engine design and properties of fuels for satisfactory service of high-speed Diesel engines. This informaiton is being sought by engine manufacturers and by the petroleum industry, and much experimental and development work is going on to improve the engine and its tolerance for fuels.

*Higher thermal efficiency of Diesel-type engines over gasoline engines.*—Diesel engines are inherently more efficient than gasoline engines; that is to say, a larger proportion of the energy content of the fuel supplied to them is transformed into useful work. Published results of comparative tests indicate that in truck service the mileage per gallon of fuel with Diesel engines is twice that with gasoline engines.

If twice the mileage per gallon can be obtained from gas oil in a Diesel engine as from fuel used in a gasoline engine, a net reduction in total demand for motor fuels might result from increased use of Diesel engines. On the other hand, increased yearly mileage per unit might compensate for the increase in mileage per gallon of fuel. However, Diesel-engine development seems more likely to reduce the demand for coal and increase that for petroleum products, as rail transport now powered almost entirely with coal is a promising field for Diesel engines.

Thus it is possible that what is now a raw material for the manufacture of gasoline may itself become a superior motor fuel, and in the main increased use of Diesel engines will mean for the petroleum industry that one of its products is substituted for another.

*Relative costs of suitable Diesel fuel and gasoline.*—On the basis of present conditions of fuel sensitivity, gas oil suitable for use in high-speed Diesel engines appears to be worth more as Diesel fuel than as cracking stock to make gasoline. Therefore increased demand for Diesel fuel will restrict supply of gas oil for cracking.

### FOR GAS MAKING

The principal technical requirements for gas oil for making or enriching manufactured gas relate to sulfur content and tendency to deposit carbon in the gas-making equipment. Demand for this purpose is not large, and available information indicates that it is likely to decrease. Two reasons are assigned for this: (a) Displacement of manufactured gas by natural gas and by liquefied petroleum gas (propane and butane), and (b) development of processes in which liquefied petroleum gases and heavy residual fuel oil can be used satisfactorily for gas making. Manufactured gas made from oil is used to enrich gas of lower heating value rather than as a primary fuel.

### AS SOLVENT FOR ASPHALTS

"Cut-back" asphalts are solutions of solid asphalt in petroleum distillates such as naphtha, kerosene, and gas oil. The purpose of "cutting back" is to provide easier handling, better penetration of the mineral aggregate, and quicker hardening or "curing" of the asphalt. The solvents evaporate or oxidize more rapidly than the lighter portions of road oils as formerly made, and the resulting deposit is said to be a better binder and to have better wearing qualities than road oil made by the older processes.

Naphthenic gas oil is more satisfactory than paraffinic gas oil as a solvent for asphalt. A great deal more naphthenic gas oil is available than paraffinic gas oil, and this fact indicates that the available supply will be governed mainly by competition with other outlets for the oil and not by scarcity in actual supply of suitable material.

No estimates are available on the volume of gas oil used in "cutting back" asphalt. However, the present emphasis on building highways at lower costs per mile by using liquid asphaltic products indicates that demand in future will increase markedly.

### AS ABSORPTION OIL

Gas oil having certain special properties is used in natural-gasoline plants and in vapor-recovery plants in refineries to dissolve vapors from gaseous mixtures. The absorption oil is used repeatedly, and consumption from unavoidable losses is small. The Bureau of Mines reports that 201,000 barrels of absorption oil was manufactured in refineries in 1937.[24]

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[24] Bureau of Mines Minerals Yearbook, 1939, p. 1004.

A satisfactory absorption oil must have definite properties that can be supplied by only a small proportion of the total supply of gas oil. However, since the consumption is small and the use to which it is put justifies a higher cost than any major channel of consumption of gas oil, no doubt an adequate supply will be available as long as a demand continues.

### SUMMARY OF GAS-OIL SITUATION

Factors affecting the demand for gas oil for various purposes may be summarized as follows:

(1) Cracking and domestic heating are not especially sensitive as to types of gas oil that can be used. These two channels of consumption make the major portion of the demand for gas oil.

The demand for gas oil for cracking is strictly on a price basis, depending on the price that can be obtained for the gas oil for other purposes, the price of other cracking stocks, including crude petroleum, and the demand for and price of gasoline.

(2) The demand for gas oil for domestic heating is a luxury demand. Almost all gas oil except highly cracked material is satisfactory for use in one or another of present types of burners, and the latter are being improved steadily.

(3) Present high-speed Diesel-type engines require fuel with special properties that can be met by only a small proportion of the total supply of gas oil. Consumption is increasing rapidly, and furthr incrase may be expected, especially if present limitations on Diesel-type engines are removed.

(4) The demand for gas oil for making gas is strictly on a price basis. Although certain properties, such as low sulfur content, low carbon residue, and low carbon-hydrogen ratio, are desirable in gas making, any or all of these properties will be sacrificed to price, as is indicated by the use of residual fuel oil for gas making.

(5) The demand for gas oil for "cutting back" asphalts depends on activity in building low-cost roads using asphalt binder. Indications at present point to an increase in this demand. Other solvents besides gas oil are employed for the purpose. Although naphthenic type gas oils are more suitable as solvents than paraffinic gas oils the fact that a great deal more naphthenic gas oil than paraffinic gas oil is available minimizes this selectivity.

(6) Absorption oil must meet special requirements that can be fulfilled by only a small proportion of the total supply of gas oil. Consumption is small.

## RESIDUAL FUEL OILS

Residual fuel oils probably are designated more correctly as "heavy fuel oils." These fuel oils are used where a viscous oil is satisfactory and where low cost is a primary consideration. In addition to true residual fuel oils, the class of heavy fuel oils includes those made by blending distillates and residues. The principal residual fuel oil is No. 6, formerly designated as "bunker C" oil.[25]

As its name implies, this oil is used as fuel for ships as well as for locomotives, stationary power plants, and other purposes where a heavy oil is satisfactory. An example of blended heavy oil is the fuel oil used by the United States Navy to meet the special requirements of Navy design and operating conditions. Blended oils also are made up for commercial purchasers who do not need oil as expensive as distillate fuel oils and yet cannot use a residual oil satisfactorily.

### MARINE FUEL

Marine service is one of the applications for which fuel oil is particularly advantageous because of its mobility, permitting storage in oddly shaped spaces not otherwise usable aboard ship; greater heating value per ton and per cubic foot of storage space; cleanliness in handling and burning, resulting in absence of dust in loading the fuel aboard ship and of cinders and soot, leaving the decks cleaner and more comfortable for passengers; reduced labor requirement for handling and firing; and other reasons, in some instances including lower total cost. Fuel oil is used in vessels propelled directly by steam engines or by oil-injection engines, and in electric-screw vessels.

The Navy is the principal consumer of heavy fuel oil in the Federal service. Available information indicates that the use of oil as fuel in naval vessels is

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[25] See footnote 21.

not on a basis of competition with coal, but because of the greater utility of oil as fuel.

Even in England, where the coal industry has been in a depressed condition for a long time and there is no indigenous petroleum, the British Admiralty has stated repeatedly that there is no intention of reverting to coal firing of British Navy vessels that now are oil burning. Proposals by spokesmen for the coal-mining industry that the Admiralty adopt dual firing (coal and oil firing aboard the same ship) also have been rejected. It may be assumed, therefore, that the United States Navy as well will continue to require fuel oil in proportion to its operations. However, the combined demand for heavy oil as fuel for other marine vessels, including tankers, is more than 10 times as great as peacetime Navy requirements.

### OTHER USES FOR RESIDUAL FUEL OILS

Heavy fuel oil is sold in a market where it is highly competitive with coal and natural gas. The chief concern of purchasers is to obtain the maximum realizable heating value at the lowest net cost. During periods of relative scarcity (high price) purchasers will waive items in specifications that they would require to be met when the market is more favorable. Apparently the demand for residual fuel oil by the railroads and by manufacturing industries is approximately equal, and together these two types of consumption originate approximately half the total demand.

Factors affecting the supply of and demand for fuel oil are largely economic rather than technologic. For example, by far the major portion of all fuel oil sold in the United States is No. 6 oil, which is used mainly in commercial operations in which cost is the primary factor in determining which of two or more choices will be adopted. The cost factor is less forceful in determining the use of oil for marine service than for railroads and many stationary power plants.

Factors that may affect the supply of heavy fuel oil include (1) decreased production of crude oil, which tends to increase demand for the heavier portions of the oil for cracking into gasoline and for other purposes, and (2) increased demand for refined products that are included in heavy fuel oil during periods of oversupply. Such products comprise (a) distillate fuel oils, (b) light and heavy lubricating oils, and (c) road oils and asphalt. Increased demand for any of these would decrease the available supply of fuel oil correspondingly, if the total supply of crude oil remained constant.

Apparently present specification requirements do not have great influence on the supply of heavy fuel oil. The principal specifications requirements are (1) flash point high enough to assure against fire hazard in storage, (2) viscosity limitation within rather wide ranges, (3) protection against oils with sludging characteristics, and (4) limitations on quantity of water and solid impurities, such as salt, lime, and sand.

Use of cracking-plant residues as fuel oil injected two new elements into the heavy-fuel-oil situation. Before the cracking process was developed heavy fuel oil was either crude oil or the product remaining after the more volatile portions of crude oil had been removed by distillation. Such a product might contain a small quantity of free water and emulsion of oil and water (usually less than 1 percent), together with a small quantity of mineral matter, such as salt, sand, and iron rust from tanks, pipe lines, and stills.

However, it was a comparatively homogeneous material. When residues from cracking plants became available as fuel oil it was found that some of these contained a relatively large quantity of carbonaceous material that settled out in storage tanks and heaters and also caused trouble by clogging preheaters and burners. Later the practice of adding lime to oil charged to stills and cracking plants to combat corrosion caused by sulfur compounds in the oil added another factor of uncertainty, in that a portion of the lime was likely to remain in the fuel oil that emerged as a residue of the process. Lime may be harmful to furnace linings and in other ways.

Improvement of heavy fuel oils with respect to sludging characteristics has been studied intensively in recent years. That these consequences of new practices in petroleum refining have not been serious factors in restricting the supply of fuel oil on the market is indicated by low fuel-oil prices that have prevailed during that time. Probably the quantity of fuel oil on the market subjected to conditions that give rise to sludging tendencies has been small in proportion to the total consumption.

The principal factor in the supply of heavy fuel oil is the production of crude oil in relation to the demand for all petroleum products. The principal factors in the demand are its price in relation to alternative fuels, such as coal and natural gas, and the availability of water power for generating electricity.

## STILL GAS

The gas recovered in petroleum refineries from storage tanks, cracking and distilling equipment, and other places where vapors arise from bodies of liquid petroleum is called refinery gas or still gas. It has attained the position of a major product of petroleum refining in point of quantity produced. Increased use of cracking processes, the re-forming of straight-run gasoline to increase its antiknock rating, and the necessity for lowering the vapor pressure of gasoline have had important parts in increasing the production of still gas.

Still gas is used principally as fuel at refineries, where it has displaced an equivalent quantity of other fuel. Refinery gas will continue to displace other fuels in petroleum refineries until a more advantageous use is found for it. Refinery gas not used for other purposes will be consumed as fuel by petroleum refiners, irrespective of the price of other fuels, because the gas is at hand and is a desirable fuel that produces high temperatures in furnaces.

Refiners recognize that burning refinery gas under stills is not justified if better and more advantageous uses can be found. To this end refinery technologists have investigated its possibilities, either as fuel in public-service corporation lines or as raw material for manufacturing motor fuels and chemical products. These processes and the products derived from them are discussed in section III of this report.

The recently developed processes using still gas for manufacture of motor fuels exemplify advances that have been made in petroleum refining in recent years toward conservation of material and disposal of products for more economic uses. Further advances in this direction may be expected as demand increases for high-octane gasoline, chemical products, and other possible byproducts of petroleum refining.

## LUBRICANTS

The largest nonfuel use of petroleum products is for lubrication, and lubricants are the most nearly indispensable products of petroleum refining. These circumstances lend particular interest to the technologic and economic aspects of lubricant supply and demand.

The 25 million privately owned passenger automobiles registered in the United States in 1938 used 40 percent of the total quantity of lubricants sold in the United States during the year. In other words, there are in the United States millions of customers for automobile lubricating oils. These customers purchase oil for cars ranging from aged and mechanically decrepit "heaps" to the latest and most luxurious products of the automobile industry. It should not be surprising that there are wide differences in the nature of the demands for automobile lubricants by individuals in this large group.

Trucks and busses comprise the next largest class of lubricant-consuming units. The total demand for this purpose is about one-eighth of the entire domestic demand. General industrial and household demand comprises the remainder.

The demand for lubricating oils has been increasing. However, the total production, including the quantities exported, has not exceeded 36 million barrels in any year—such a small quantity in proportion to the crude oil produced annually in the United States that it does not seem likely that there can be any scarcity of lubricants for many years. The domestic demand varies with industrial activity and with general economic conditions, and export demand has fallen steadily, owing primarily to policies of foreign governments that have virtually required refining of petroleum within their respective countries.

Although certain animal and vegetable oils and fats have lubricant properties, it is difficult to conceive how the present demands for lubricants for heavy, high-speed machinery could be met if petroleum were not available. In fact, it is doubtful whether our machine age could have developed without the plentiful supply of stable, efficient lubricants that has been made from petroleum. The demand for lubricants probably will be met despite demands that may be made for any other petroleum products.

Modern automobile engines, with their high operating speeds, high compression ratios, and high bearing pressures, together with high temperatures in the combustion chambers, contrasted with low atmospheric temperatures, impose stringent requirements upon lubricating oils for satisfactory service under these severe operating conditions. The large variety of industrial machinery also imposes stringent requirements of stability and performance characteristics upon lubricants.

Fortunately, the volume and characteristics of lubricating oil manufactured can be varied over rather wide limits, according to demand. Solvent-refining processes have been most influential in increasing the number of crude oils available for the manufacture of high-grade lubricating oil, and crude oils that have been used for the manufacture of lubricants in the past will yield improved lubricating oils by these processes. In addition to improvement in lubricating quality, these lubricating oils have a longer useful life.

## ASPHALT AND ROAD OILS

The striking and important difference between asphalt and road oils in comparison with all other important types of petroleum products is that they are sold to ultimate consumers on the basis of specifications, largely by competitive bidding. Another difference is that unit sales are in large quantities, measured in tons rather than in quarts, gallons, or barrels. Municipal, State, and Federal road-building agencies are the largest purchasers of asphalt and road oils.

The significance of buying on specifications is that asphalt and road oils are defined commodities, in which respect they are similar to gasoline. However, ultimate consumers are little concerned with gasoline specifications, and these have been evolved as a result of cooperative studies by petroleum refiners, automotive engineers, and Federal agencies. On the contrary, asphalt manufacturers who wish to bid for contracts to supply asphalt or road oil must strive to meet requirements of specifications at a manufacturing cost low enough to enable them to make bids below those of their competitors. It seems evident that this practice is not conducive to quality of product.

In the past, asphalt and road-oil specifications have been exceedingly diverse, although the situation in this respect is improving. The conclusion is inescapable, however, that many specifications now in force are highly empirical. The following statement by E. F. Kelley,[26] United States Bureau of Public Roads, gives a résumé of the situation:

"Much has been said and written in recent years of the importance of low cost in the development of an adequate highway system, and of the importance in this development of liquid asphaltic materials. The facts are so generally recognized that it is unnecessary to repeat here any of the statistical data which support them. It is sufficient to say that there are hundreds of thousands of miles of public highways which require a smooth, dustless, all-weather surface, but which do not now—and probably never will—carry a traffic heavy enough to justify more than an improvement of low cost. The possible market for liquid asphalts, for use in the present and future construction and maintenance of road surfaces of this character, is enormous.

"Liquid asphalts of satisfactory quality have all the requisites of good binding materials for the mineral aggregates which furnish the stability and abrasive resistance of road surfaces. Since they are relatively inexpensive, these binders occupy a position of special importance in the field of low-cost highway construction. However, if economical construction is to result from their use, they must have certain essential qualities; and these qualities can be insured only by adequate specification requirements.

"In the period during which the consumption of liquid asphalts for road construction gradually developed to the present enormous quantities, there also developed a condition of chaos in the specifications of the various consumers. Different tests, combinations of tests, and required test limits in specifications for materials of essentially the same character created a confusion which was detrimental alike to producer and consumer. For instance, a survey in 1930 of State highway department specifications for liquid asphaltic products showed that there were in use, including all variations, a total of 119 different tests. The practice of the different States varied greatly with respect to the selection of the tests and combinations of tests required for materials of similar char-

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[26] Kelley, E. F., Specifications for Liquid Asphaltic Materials for Low-Cost Roads: Paper presented at the 3d midyear meeting, American Petroleum Institute, Tulsa, Okla., May 19, 1933.

acter. The situation was further complicated by the lack of agreement regarding test results, or test limits, which should be specified. The net effect of the nonuniform practice with respect to the requirements for both tests and test limits has been the establishment of a unduly large number of grades of material. This has placed on manufacturers the burden either of carrying a large stock of different grades or of being prepared to manufacture, on short notice, materials to meet the wide variations required by the specifications of the different states. Naturally, the result has been increased costs, which, in the end, have been charged to the consumer.

"The essential characteristics of liquid asphaltic materials which must be guaranteed by adequate specifications are ability to coat the particles of mineral aggregate, to adhere to them permanently and bind them together, and to resist the disintegrating effects of the action of the elements."

The quotation from Kelley indicates that specifications for liquid asphaltic road materials at the time the statement was written produced confusion and increased costs. Apparently conditions have been improved to some extent since that time. However, the difficulty caused by the great number of diverse specifications for materials for the same purpose still exists. Many of the items in specifications also seem to have no direct relationship to the purpose for which the materials are to be used. Apparently the remedy lies in additional study of essential properties of liquid asphaltic materials and general acceptance of uniform specifications embodying the best opinion regarding essential characteristics of products. Also, more rational specifications probably would lower ultimate costs by decreasing the number of grades that have to be kept on hand and would avoid the necessity of making special products to meet requirements for less rational specifications.

### USES

The supply of and demand for asphalt and road oils is ably treated by A. H. Redfield, of the Bureau of Mines, in the chapter on Asphalts and Related Bitumens in the annual volumes of the Bureau of Mines Minerals Yearbook.

Approximately 60 percent of all asphalt produced in the United States is used for street paving and road building and approximately 25 percent in the manufacture of prepared roofing. Only 5 percent in 1937, and only 4 percent in 1936, was sold to foreign countries. The remainder is employed for waterproofing, briquetting, pipe coating, as an ingredient of paints, varnishes, and lacquers, and for a variety of other uses. A recent innovation in asphalt utilization is its use in underwater construction, such as for flood control and harbor protection. In flood control the asphalt is used in waterproofing and reinforcing the sides and bottoms of rivers, canals, ditches, and reservoirs. Harbors are protected from heavy seas by employing asphalt in the construction and repair of jetties and breakwaters. This type of utilization seems likely to create a large new demand for asphalt. Road oil is used almost exclusively for road building and maintenance. Apparently no road oil is exported.

### SUMMARY

In addition to the use of asphalts in street paving and arterial highways, petroleum asphalts and road oils (liquid asphaltic products) have an important place in the development of an adequate system of low-cost highways with a smooth, dustless, all-weather surface but not carrying traffic heavy enough to require high-cost paving, affording an enormous possible market for liquid asphalts. The petroleum-refining industry in the United States has resources of raw material and manufacturing equipment to supply a much larger quantity of such material than has been consumed in the past. Availability of satisfactory materials for this purpose can best be assured by general acceptance of adequate specifications embodying requirements as to quality.

The demand for asphaltic products for roofing, waterproofing, and paints is related to activity in construction work.

### PARAFFIN WAX

The following statement by Espach[27] is a concise summary of the manufacture and uses of paraffin wax:

"Paraffin wax is an interesting and valuable product obtained in the refining of many crude petroleums. Petroleum when refined is separated into a number

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[27] Espach, Ralph H., Manufacture of Paraffin Wax from Petroleum: Bureau of Mines Bull. 388, 1935, pp. 1, 2.

of fractions by vaporization and fractionation. One of the most important of these is a lubricating-oil fraction from which wax, if present, must be removed before the manufacture of satisfactory lubricants is possible. Most of the Eastern, Mid-Continent, and Rocky Mountain petroleums contain wax, while the majority of the Gulf coast and many of the California petroleums are free of wax. The removal of wax from lubricating-oil fractions is a rather expensive refining operation. The equipment necessary for wax removal is costly, but it has long life and its maintenance costs are low. The equipment for finishing the crude wax into commercial products is not costly compared to that for removing the wax from the oil. As the cost of wax removal is chargeable to the lubricating oil, the actual refining of the crude wax into commercial products should be profitable even with the low prices for wax that have obtained for several years. * * *

"Although wax is a necessary byproduct in the manufacture of most lubricating oils, it also has major economic importance.

"The production of commercial wax is closely related to the production of lubricants because of the necessity for removing wax from lubricant stocks, but it does not necessarily follow production of lubricants. The market demand for wax determines whether the crude wax is refined further into commercial waxes or whether it is used as cracking stock for the production of motor fuel. Thus the quantity of wax produced could be increased should demand warrant. * * * The amount imported has been small, but it consists of the higher-melting-point grades. Practically all of the imported wax comes from the Netherland East Indies and British India.

"Since paraffin wax has convenient melting points, will bend, and is tenacious at ordinary temperatures, does not deteriorate, is impervious to water, and has a high dielectric strength, it is used extensively in the manufacture of candles; the impregnation of waxed papers; the coating of paper cartons (butter, cheese, ice cream), drinking cups, milk bottles, and milk-bottle tops; electrical insulation; waterproofing; the impregnation of match tips; floor and furniture polishes; laundering; the protection of preserves and jams from fermentation; coatings for cheeses to improve their appearance and prevent mold, evaporation, and shrinkage; the lining of butter tubs; coatings for beer vats and barrels (vinegar, cider, alcohol, whisky, molasses, and sauerkraut); coatings for meats, sausages, and other products which must be prevented from drying; protective wax dressings for burns; the manufacture of artificial flowers; etching glass; miners' lamps and marine bunker lights; waxing yarns in the textile industry; stuffing or loading of leather in tanneries; and for numerous other materials and purposes."

The most important use for paraffin wax is for manufacturing waxed paper and for other forms of moistureproofing. Use of paraffin wax for these purposes probably can be replaced at a greater cost by substituting hard-surfaced paper, specially processed cardboards, metal-lined containers, or other materials such as vegetable waxes and rubber. Candles can be made from animal and vegetable fats and waxes, such as tallow and bayberry wax. However, to supply a demand approximating the present consumption of candles probably would increase their price to such an extent that use would be restricted to ornamentation and religious ceremonies.

It appears likely, therefore, that as long as it can be sold at about the present wholesale price of approximately 2.5 cents per pound a demand for large quantities of paraffin wax will continue; apparently this can be met at present from petroleum only. No practical substitute appears to be available in sufficient quantity at comparable cost, and the unique properties of the material make it very desirable for the purposes for which it is employed. Any replacement of candles by kerosene, gas, or electricity probably will be balanced by increased use of paraffin for one or more of its other applications.

## PETROLEUM COKE

Petroleum coke is a cellular product of the decomposition of petroleum, similar in appearance to some forms of coke made from coal. It is produced in petroleum refineries as a byproduct of cracking and by destructive distillation of petroleum at atmospheric pressure. It is a true byproduct of petroleum refining in that it almost never is produced to supply a demand but rather is an unavoidable result of refining operations conducted for other purposes.

Some years ago petroleum coke was a relatively high-priced commodity, but during the past several years it has been sold in competition with coal, largely on a basis of price. When experience in burning coke in residential heating equipment has been acquired, it is a very satisfactory fuel, as it has high heat value, is smokeless, and usually contains less than 2 percent—often less than 1 percent—ash.

Use of petroleum coke as fuel in petroleum refineries has declined steadily since 1930, as the demand for coke in domestic heating has increased and production has decreased. In addition to its use as fuel, petroleum coke is employed in the manufacture of graphite electrodes and crucibles and electric furnace linings and for other purposes for which an inexpensive form of comparatively pure carbon is advantageous.

Although the marketed production of petroleum coke is not an important factor in the fuel supply of the United States the domestic demand of more than 1 million tons per year is another item of considerable magnitude added to the total quantity of petroleum fuels consumed in the United States.

## LIQUEFIED PETROLEUM GAS

The principal constituents of liquefied petroleum gases are propane ($C_3H_8$), butane ($C_4H_{10}$), and a small amount of pentane ($C_5H_{12}$). Propane and butane are liquids at low temperatures or under pressure but will evaporate readily from a container equipped with a pressure-relief valve in which they are held under their self-induced pressure at temperatures above the freezing point of water or even lower. This physical property of these readily combustible liquids is the basis of their use as "bottled gas." They are burned for cooking and water heating in equipment that differs only in the details of burner design from the better grades of equipment used for city gas.

Liquefied petroleum gases are not marketed in large quantities from petroleum refineries in the United States. Minerals Yearbook 1939 reports 577,000 barrels (24,234,000 gallons) of liquefied petroleum gases manufactured at petroleum refineries in the United States in 1937, of which 528,000 barrels (22,176,000 gallons) was manufactured in the East Coast and Indiana-Illinois-Kentucky refinery districts. During the same year 2,789,600 barrels (117,116,000 gallons) of liquefied petroleum gases manufactured at natural-gasoline plants was sold in the United States. There are no natural-gasoline plants in the East Coast refinery district, and the combined capacity of those in the Indiana-Illinois-Kentucky district is small. Consequently, it appears likely that liquefied petroleum gases can be made profitably at petroleum refineries in localities where local natural-gasoline plants cannot supply the demand. The list of producers of these gases published by the Bureau of Mines shows that the majority of producing organizations are subsidiaries of companies that refine petroleum. Moreover, these materials have great inherent potentialities as raw material for manufacturing chemicals. Nevertheless, the principal reason for discussing liquefied petroleum gases in this report is that they are used by a large number of consumers. Sales of liquefied petroleum gases have grown from 39 million gallons in 1933 to 165 million in 1938, of which nearly 56 million gallons was sold as domestic fuel.

Sales of these gases for the manufacture of chemicals (32,299,000 gallons) were 21 percent greater in 1938 than in 1937. Although in this respect the petroleum industry is not functioning as a chemical industry, it is the source of supply of raw material for a large and rapidly growing branch of the chemical industry and it appears not unlikely that if the market for the chemicals made from these gases should expand enough they would be made at petroleum refineries or natural-gasoline plants.

The sale of liquefied petroleum gases for use as fuel in internal-combustion engines has grown steadily. Delivery of 20,914,000 gallons for this purpose in 1937 represented a gain of 23 percent over the 1937 demand—16,987,000 gallons. Liquefied petroleum gases have proved quite satisfactory as fuel in heavy-duty automotive equipment and power engines, and further developments along this line may be expected.

The expanded utilization of this former waste product of natural-gasoline manufacture is another example of the conversion of a product of little value into a convenient and valuable commodity, exceedingly useful for a variety of purposes.

The annual chapters of the Minerals Yearbook on Natural Gasoline and Liquefied Petroleum Gases give specific evidence of the growth of this industry in volume and in variety of uses.

## DISTRIBUTION OF CONSUMPTION OF PETROLEUM PRODUCTS

The opinion seems to be held rather widely, even among those who have studied the subject, that the major portion of all petroleum products is consumed in the course of industrial and commercial activities. Published discussions also leave the impression that petroleum is the major source of energy used in certain large groups of industries, such as transportation. One is also led to conclude that use of petroleum products by the Army and Navy represents a large proportion of consumption. In the following pages the evidence on these points will be reviewed.

### USE OF PETROLEUM PRODUCTS BY TRANSPORTATION INDUSTRIES

The Energy Resources Committee of the National Resources Committee, in its summary of the Report on Energy Resources and National Policy, states:[28]

"In terms of products, one might characterize the first 40 years of the oil industry as designed for illumination and the past 30 years as designed for power. The present great economic importance of petroleum results from its use in transportation industries and, primarily, of course, in the operation of motor vehicles—automobiles, busses, trucks, tractors. The importance of oil in the transportation industries stems also from the widespread use of residual fuel oil and Diesel oil by ships and railroad locomotives, and the use of gasoline for airplanes and motorboats. The entire motor transport is dependent on petroleum products, and it has been estimated that for all the methods of transportation approximately 60 percent of the power requirements are supplied by gasoline or by fuel oil. For all practical purposes it may be said that 100 percent of the energy requirement of automobiles and airplanes is derived from gasoline; 93 percent of the total tonnage of ocean-going vessels of the United States merchant marine is moved by oil either in Diesel motors or as fuel under boilers; and practically all vessels of the United States Navy are powered by fuel oil or gasoline. Perhaps no product has produced more economic and social changes than gasoline, as the entire fabric of the transportation system has been changed by the use of automobiles and airplanes. Without gasoline our agricultural industry might revert to horse and mule power, but our urban commerce and manufacturing industries could not maintain their present organization without gasoline."

This paragraph undoubtedly reflects the opinion that "transportation industries" are the major consumers of petroleum products. It appears to be of interest to analyze this opinion in the light of available data:

Transportation industries, as distinguished from individually owned means of transportation, may be divided into the following categories:

(1) Truck and bus transportation.
(2) Rail transportation.
(3) Water-borne transportation.
(4) Civil and commercial aviation.

Two major questions arise regarding these means of commercial transportation: (1) What proportion of their fuel requirements is supplied by the petroleum industry, and (2) What is the proportion of the quantity of petroleum fuel used in this way to the total domestic demand for petroleum fuels? The answers to these questions, to the degree of accuracy that the available data permit, will appear on the following pages.

### TRUCK AND BUS TRANSPORTATION

Trucks and busses are the largest consumers of petroleum fuels among the transportation industries, and petroleum products are the only fuels used in them, except a relatively small number of electric trucks and electric (trolley) busses. In this industry the principal fuel is gasoline, although it is being displaced to a small degree, on the one hand by Diesel fuel, and on the other by propane-butane mixtures, butane, and propane.

The available data on fuel used in trucks and busses are given in table 43. In addition to the quantities of fuels listed in the table, an unknown quantity of Diesel fuel oil was consumed by trucks and busses, and the energy employed

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[28] Energy Resources Committee, Energy Resources and National Policy: Rept. to the National Resources Committee, Washington, D. C., January 1939, p. 20. For sale by the Superintendent of Documents, Washington, D. C., price $1.00; also House Document No. 160, 76th Cong., 1st Sess., Feb. 16, 1939.

by a relatively small number of electric trucks and electric (trolley) busses probably was generated at coal or hydroelectric plants. However, it does not seem probable that if the figures were known, the quantities of fuel used to drive Diesel and electric trucks and busses would make a significant change in the total given in the table.

TABLE 43.—*Fuel used in trucks and busses, 1937–38* [1]

[Thousands of barrels of 42 U. S. gallons]

| | 1937 | 1938 [2] |
|---|---|---|
| Gasoline: | | |
| Trucks: | | |
| Highway | 39, 723 | 40, 649 |
| City | 63, 084 | 60, 973 |
| Total trucks | 102, 807 | 101, 622 |
| Busses | 15, 500 | 15, 300 |
| Liquefied petroleum gases [3] | [2] 404 | [2] 498 |
| Total | 118, 711 | 117, 420 |

[1] Bureau of Mines Minerals Yearbook 1939.
[2] Subject to revision.
[3] Reported as internal-combustion-engine fuel; may include some fuel used in stationary engines.

It is important, however, to note the figures in table 43 relating to fuel used in trucks operated in cities. These include hundreds of thousands of trucks owned and operated as adjuncts to one- and two-truck mercantile establishments, such as neighborhood food stores. To classify these truck operations as part of "the transportation industries" seems to be a rather broad use of the term, but since these trucks are used commercially rather than for pleasure or recreation, and since they are grouped in the statistics with heavy-duty trucks, they are included in this tabulation. The important consideration is that this large number of small trucks in all probability uses a high proportion of the total fuel consumed by trucks and busses.

### RAIL TRANSPORTATION

*Steam, Diesel, and gasoline locomotives.*—Complete statistics apparently are not available to indicate the quantities of various fuels used to energize the several forms of rail transport. Table 44 is a compilation of the best available data on fuel used in 1937 and 1938 to operate railroads powered by steam, Diesel, and gasoline engines. Assuming 4 barrels of petroleum fuel to be equivalent to 1 ton of coal, the petroleum fuel consumed by railroads in 1937 is equivalent to 17,543,000 tons of coal, or 17.5 percent of the total coal and oil fuel used by these railroads. For 1938 the comparable figures are 13,854,000 tons and 16.6 percent.

*Electric railways.*—Table 44 omits railroads powered by electricity, interurban electric railways, and street railways. This group of commercial transportation mediums represents a large number of passenger-miles of transportation and carries some freight. Apparently no data are available as to the quantities of electricity derived from water power, coal, and petroleum fuels for use in these operations. Consequently, recourse must be had to data on public-utility electric plants to draw such conclusions as seem to be warranted. Data published by the Bureau of Mines [29] disclose that 44,766,000 tons of coal, 14,143,000 barrels of fuel oil, and 170,567 million cubic feet of natural gas were sold to public-utility power plants during 1937. The National Resources Committee states [30] that "in 1937 more than 36 percent of the electricity produced by utilities was from hydro plants."

These figures probably have little quantitative relation to the amount of fuel and water power used to generate electricity for railways. However, assuming that water power, coal, natural gas, and petroleum fuel were used in the same proportion to generate electricity for electric railways as for public-utility power plants as a whole, the figures may be used to calculate a hypothetical proportion between the quantity of petroleum fuel and of coal used for electric-railway

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[29] Minerals Yearbook, 1939, pp. 773, 990, 1016.
[30] Energy Resources Committee, work cited in footnote 28, p. 269.

service. Assuming 4 barrels of fuel oil equivalent to 1 ton of coal the petroleum fuel used for public-utility power plants in 1937 is equivalent to 3,260,000 tons of coal or 7.3 percent of the coal used. Assuming 1 ton of coal equal to 26 million B. t. u. and 1,000 cubic feet of natural gas equal to 1 million B. t. u., 170,567 million cubic feet of natural gas is equivalent to 6,560,000 tons of coal. On the basis of the Energy Resources Committee's estimate (36 percent), the electricity generated by hydroelectric plants was equivalent to 30,692,000 tons of coal.

From these data the conclusion seems inevitable that the largest of our transportation industries, rail transportation, obtains the major portion of its power from coal, with hydroelectric power next in importance, and that only a minor fraction of its fuel requirements is supplied by the petroleum and natural-gas industries.

TABLE 44.—*Fuel used by steam-, gasoline-, and Diesel-powered railroads, 1937–38*

| Fuel | 1937 | 1938 |
|---|---|---|
| Residual oil [1] | 67, 829 | 53, 119 |
| Diesel oil [1] | 610 | 550 |
| Other gas oil and distillate [1] | 1, 019 | [4] 975 |
| Gasoline [1] [2] | 714 | 773 |
| Total petroleum fuel [1] | 70, 172 | 55, 417 |
| Coal [3] | 82, 667 | 69, 675 |

[1] Thousands of barrels of 42 United States gallons.
[2] Authority: Interstate Commerce Commission.
[3] Thousands of net tons.
[4] Bureau of Mines estimate.

### WATER-BORNE TRANSPORTATION

Data on fuel used in commercial transportation by water are not conclusive. Apparently the best means of estimating quantities of various fuels used in transportation by water is by comparing the available data for Diesel and residual fuel sold for marine use with statistics on documented machinery-propelled vessels. The data in table 45, in which documented vessels are grouped according to the type of motive power used, include all vessels which are not used exclusively for pleasure and are of 5 net tons or over. Evidently these data give a more complete representation of existing facilities for commercial water transportation than is obtained by considering only vessels of 100 gross tons or over, or ocean-going vessels of the United States merchant marine. The quotation from the National Resources Committee states that "93 percent of the total tonnage of ocean-going vessels of the United States merchant marine is moved by oil either in Diesel motors or as fuel under boilers." However, as will be seen by reference to table 45, approximately 27.5 percent of the tonnage of documented ships is coal burning. Large numbers of small boats with average rating of 11 gross tons are listed as driven by "gas engines," which probably means that their fuel is either automobile gasoline or a similar fuel. Most of these many small vessels probably are not engaged in commercial activities but are individually owned for pleasure or recreation, and therefore are not part of the transportation industries.

Study of available statistics shows definitely that the statistics for coal served to bunkers of ships in foreign trade represent only a minor fraction of the coal consumed in generating power for water-borne transportation. Thus, table 45 indicates that the tonnage of coal-burning documented vessels is approximately 27.5 percent of the total tonnage of documented vessels. Ships using oil fuel are reported to have consumed 84,990,000 barrels of oil in 1937. Using a factor of 4 barrels of oil equivalent to 1 ton of coal, this quantity of oil is equivalent to 21,247,500 tons of coal. It may be assumed, without too great error, that the coal-burning ships used coal in proportion to their share of the total tonnage of documented ships. On this assumption, the quantity of coal consumed by coal-burning ships was 8,070,000 tons. In contrast to this figure, the Bituminous Coal Commission, in a chapter contributed to Bureau of Mines Minerals Yearbook, 1938, reports 1,832,000 tons of coal served to bunkers of ships in foreign trade in 1937. Evidently the major portion of the coal used in water transportation is not covered in statistics.

TABLE 45.—*Documented machinery-propelled vessels of the United States as of June 30, 1937* [1]

| Type of vessel | Number | Gross tons |
|---|---|---|
| Oil fuel | 7,110 | 8,254,007 |
| Coal burning | 2,696 | 3,294,675 |
| Electric screw [2] | 108 | 301,621 |
| Gas engine | 9,435 | 103,774 |
| Total | 19,349 | 11,954,077 |

[1] Bureau of Marine Inspection and Navigation.
[2] Power generated by various fuels.

### CIVIL AND COMMERCIAL AVIATION

The available data on fuels used in civil and commercial aviation are given in table 46. The quantities obviously are insignificant compared with the total demand for petroleum fuels. Fuel used in military aviation is included for comparison, although that is not a transportation industry.

TABLE 46.—*Fuel used in aviation* [1]

[Thousands of barrels of 42 United States gallons]

| Type of service | 1937 | 1938 |
|---|---|---|
| Scheduled air lines | 986 | [2] 1,079 |
| Miscellaneous flying | 253 | [2] 243 |
| Total civil and commercial | 1,239 | 1,322 |
| Army | 484 | 576 |
| Navy | 347 | 426 |
| Coast Guard | 39 | 40 |
| Other Government agencies | -------- | 28 |
| Total Government use | 870 | 1,070 |

[1] Authority: Air Commerce Bulletin, Bureau of Air Commerce.
[2] Civil Aeronautics Authority.

### SUMMARY

The foregoing analysis of sources and quantities of energy used in the transportation industries may be summarized as follows:

Trucks and busses are the largest industrial outlet for petroleum fuels, and virtually all the energy used to drive them is derived therefrom. Exceptions are a relatively small number of electric trucks and electric (trolley) busses.

Petroleum supplied approximately 17 percent of the fuel used in 1937 and 16 percent of that used in 1938 for steam-, diesel-, and gasoline-powered locomotives. The sources of power used to operate electric railways apparently were distributed as follows in 1937: Coal, 52.5 percent; hydroelectric power, 36 percent; natural gas, 7.7 percent; and fuel oil, 3.8 percent.

Petroleum fuels comprised approximately 72.5 percent of the fuel used in machinery-propelled documented ships in 1937, and the remaining 27.5 percent was coal.

The petroleum industry supplies all the fuel used in aviation. The quantity is insignificant compared with the total quantity of petroleum fuels, but the demand is increasing rapidly.

### PETROLEUM PRODUCTS USED FOR OTHER PURPOSES THAN COMMERCIAL TRANSPORTATION

It will now be in order to derive such conclusions as may be warranted by accuracy of the available data as to the quantities of petroleum products used for other purposes than commercial transportation and the number of users of petroleum products. The fundamental fact in connection with utilization of petroleum products is that more than 90 percent of the total quantity of all petroleum products is burned, for lighting, heating, and generating power. The second important consideration is that residents of the United States, in their individual capacities, as distinguished from organized transportation systems, are the largest consumers of petroleum products. Lubrication is the largest nonfuel use of petroleum products.

### MOTOR GASOLINE

America's more than 25 million privately owned passenger automobiles are by far the largest consumers of petroleum products, and of all these commodities gasoline is the largest class. In Bureau of Mines statistics, "motor fuel" means gasoline derived from petroleum by straight running and by cracking, from natural gasoline, and by blending with benzol. According to Bureau of Mines statistics,[31] motor fuel manufactured in the United States during 1938 comprised the constituents shown in table 47.

TABLE 47.—*Constituents of motor fuel, 1938* [1]

| Constituent | Thousands of barrels | Percent |
|---|---|---|
| Straight-run gasoline | 245,418 | 43.2 |
| Cracked gasoline | 270,471 | 47.6 |
| Blended natural gasoline | 39,961 | 7.1 |
| Unblended natural gasoline | 10,356 | 1.8 |
| Benzol | 1,699 | .3 |
| Total | 567,905 | 100.0 |

[1] Bureau of Mines Minerals Yearbook 1939, p. 979.

Almost all gasoline sold at service stations in the United States consists of the first three ingredients listed in table 47, and benzol-blended motor fuels are a relatively small proportion of the total quantity. Although conclusive data are not available, the average benzol content of benzol blends probably is at least 10 percent, which would indicate that the quantity of benzol blends manufactured does not exceed 3 percent of the total production of motor fuel. Aviation gasoline is included statistically in motor fuel, but propane-butane mixtures and Diesel fuel oil used as motor fuel are not included.

Tables 48 and 49 give information on the distribution of domestic demand for motor fuel and the number of motor vehicles of various classes in use. These tables show that privately owned passenger cars consumed nearly three times as much motor fuel in 1938 as trucks and busses.

TABLE 48.—*Distribution of domestic motor-fuel demand, 1936–38* [1]

[Thousands of barrels of 42 gallons]

| | 1936 | 1937 [2] | 1938 [3] |
|---|---|---|---|
| Passenger cars: | | | |
| Highway | 150,896 | 161,302 | 161,390 |
| City | 170,128 | 182,614 | 185,963 |
| Total passenger cars | 321,024 | 343,916 | 347,353 |
| Trucks: | | | |
| Highway | 35,462 | 39,723 | 40,649 |
| City | 57,643 | 63,084 | 60,973 |
| Total trucks | 93,105 | 102,807 | 101,622 |
| Busses | 14,500 | 15,500 | 15,300 |
| Total automotive demand [4] | 428,629 | 462,223 | 464,275 |
| Other demand | 52,977 | 57,129 | 57,382 |
| Grand total | 481,606 | 519,352 | 521,657 |

[1] Bureau of Mines Minerals Yearbook 1939, p. 977.
[2] Revised figures.
[3] Subject to revision.
[4] 89 percent of total motor-fuel demand.

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[31] Bureau of Mines, Minerals Yearbook 1939, p. 979.

TABLE 49.—*Motor vehicles, registered and tax exempt, 1937–38* [1]

| | 1937 | 1938 |
|---|---|---|
| Passenger cars [2] | 25, 405, 728 | 25, 213, 601 |
| Motor trucks and busses | 4, 299, 492 | 4, 272, 079 |
| Total registered motor vehicles | 29, 705, 220 | 29, 485, 680 |
| Tax-exempt official cars | 104, 792 | (4) |
| State and local [3] | 231, 280 | (4) |
| Total tax exempt | 336, 072 | (4) |
| Total motor vehicles in use | 30, 041, 292 | (4) |

[1] Authority: Public Roads Administration.
[2] Includes taxicabs and some busses.
[3] Some States require county and municipally owned vehicles to pay registration fees. In those States these vehicles are included among regular registrations.
[4] Figures not yet available.

### KEROSENE AND RANGE OIL

The large and increasing demand for kerosene and range oil noted in the 1934 report has continued through 1938. Data on sales of kerosene and range oil in 1937 are available in greater detail than in previous years. Detailed statistics for 1938 are not yet available. Tables 50 and 51 are compilations of Bureau of Mines data, showing the growth of total demand for kerosene and the quantities consumed in 1937 as range oil and tractor fuel and for all other uses. The domestic demand for kerosene given in table 50 for 1938 was 46.4 percent greater than in 1933.

TABLE 50.—*Demand for kerosene, 1932–33 and 1937–38* [1]

[Thousands of barrels of 42 gallons]

| | 1932 | 1933 | 1937 | 1938 [2] |
|---|---|---|---|---|
| Domestic demand | 33, 221 | 38, 493 | 54, 972 | 56, 351 |
| Export | 11, 044 | 8, 959 | 8, 886 | 7, 513 |
| Total demand | 44, 265 | 47, 452 | 63, 858 | 63, 864 |

[1] Bureau of Mines Minerals Yearbook.
[2] Subject to revision.

TABLE 51.—*Sales of kerosene and range oil in 1937* [1]

[Thousands of barrels of 42 gallons]

| Product: | |
|---|---|
| Range oil (No. 1 fuel oil) | 2, 481 |
| Kerosene sold as range oil | 30, 099 |
| Total range oil | 32, 580 |
| Kerosene sold as tractor fuel | 4, 251 |
| Kerosene: All other uses | 20 201 |
| Total kerosene | 54, 551 |
| Total range oil and kerosene | 57, 032 |

[1] Bureau of Mines Minerals Yearbook 1939, p. 988.

The principal outlet for this marked increase in domestic demand is indicated by statistics of the Bureau of the Census on the production of kerosene- and range-oil-fueled stoves and heaters. Table 52 gives these figures for 1935 and 1937. Assuming that production in 1936 equaled the average of the quantities produced in 1935 and 1937, it appears that, in the 3-year period, 1935–37, more than 6 million kerosene- and range-oil-burning units were added to the large number already in service at the beginning of 1935.

There seems to be little reason to doubt that kerosene and range oil are used for cooking and heating mainly by individual householders, and table 51 shows that more than 30 million barrels of kerosene were sold for that purpose in 1937, or 54.8 percent of the domestic demand.

TABLE 52.—*Production of kerosene- and range-oil-fueled stoves and heaters, 1935 and 1937* [1]

| Type of unit | 1935 | 1937 |
|---|---|---|
| Kerosene- and range-oil stoves | 881, 228 | 1, 268, 762 |
| Kerosene room heaters | 613, 731 | 907, 353 |
| Kerosene- and range-oil water heaters | 64, 486 | 59, 572 |
| Range-oil burners [2] | 134, 968 | 179, 427 |
| Total | 1, 794, 413 | 2, 415, 114 |

[1] Authority: Bureau of the Census.

[2] Used to convert stoves and water heaters from coal or other fuel to oil burning.

### DISTILLATE AND RESIDUAL FUEL OILS

Statistics of the Bureau of Mines for several years prior to 1936 treated gas oil and distillate fuel oil as a single commodity. Beginning in 1936 statistics on gas oil and distillate fuel oil have been reported in greater detail, and it will be possible in future to gain more accurate knowledge of the quantitative distribution of demand for these oils. Data for 1938 are not yet available. The discussion that follows will direct attention to sources of similar data for future years.

It is of considerable interest to know the quantities of each of the six commercial-standard grades of fuel oil that make up the total annual sales of heating oils in the United States. The Bureau of Mines has published data [32] that can be used to calculate an estimate. Data are given in the Bureau report for sales of fuel oil of grades 1 to 6 for each of the States except California, Oregon, Washington, Arizona, and Nevada. In those just mentioned, heating oils are not sold by numbered grades, as in other parts of the country, but are designated as stove distillate, Diesel fuel, light fuel oil, and heavy fuel oil, which correspond approximately and in the same order to numbers 1, 3, 5, and 6 as delivered elsewhere. Pacific coast sales of heating oils in 1937 were reported to total 8,845,000 barrels, divided between 2,988,000 barrels of light or distillate fuel oils and 5,857,000 barrels of heavy or residual fuel oils. Table 53 shows sales of heating oils by grades for 1937, as reported in Bureau of Mines Statistics, except that the distribution among grades for the California area is on an estimated basis.

*Sales of heating oils.*—The data in table 53 indicate definitely that No. 2 and No. 3 fuel oils comprise the major portion of the oil used for domestic oil burners, and when the figures for 1938 and 1939 become available they probably will show that No. 2 fuel oil constitutes a still larger proportion of the quantity of domestic fuel oil sold. The quantity of No. 1 fuel oil is one-sixth of the quantity of No. 2 fuel oil. No. 5 and No. 6 fuel oils are used for heating larger buildings, such as apartments, theaters, and hotels.

TABLE 53.—*Sales of heating oils in the United States in 1937* [1]

[Thousands of barrels of 42 gallons]

| Grade of oil: | *Sales* |
|---|---|
| 1 | 8, 221 |
| 2 | 49, 667 |
| 3 | 15, 268 |
| 4 | 8, 045 |
| 5 | 12, 133 |
| 6 | 23, 249 |
| Total, grades 1 to 6 | 116, 583 |

[1] Estimated from data in Bureau of Mines Mineral Market Report 708, Fuel Oil and Kerosene Sales Establish New Records in 1937, by A. T. Coumbe, associate economic analyst.

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[32] Coumbe, A. T., Fuel Oil and Kerosene Sales Establish New Records in 1937: Bureau of Mines Mineral Market Report 708, February 1939.

Table 54 summarizes Bureau of Mines statistics on sales of fuel oil in the United States in 1937 according to types of services for which the major classifications of fuel oil were used. It is notable that "heating oils" is the largest item in the totals by types of service. Fuel oil used by the United States Army, Navy, and Coast Guard is the smallest item in the total by types of service.

Comparison of the separate items that comprise the total in table 54 with Bureau of Mines figures for indicated domestic demand for gas oil and residual fuel oil in 1937 indicates that heating oils, Navy-grade fuel oil, and possibly Diesel fuel oil contain some residual oil, as well as gas oil and distillate. Navy-grade fuel oil, the largest item in the total for military uses, is approximately equivalent in characteristics to No. 5 fuel oil.

TABLE 54.—*Sales of gas oil and distillate fuel oil and residual fuel oil in the United States, 1937* [1]

[Thousands of barrels of 42 gallons]

| Type of service | Kind of oil | | | Total |
|---|---|---|---|---|
| | Gas oil and distillate fuel oil | Diesel fuel oil | Residual fuel oil | |
| Heating oil [2] | 81,201 | | 35,382 | [2] 116,583 |
| Railroads | 1,019 | 610 | 67,829 | 69,458 |
| Vessels, including tankers | | 13,494 | 71,496 | 84,990 |
| Gas and electric power plants | 1,981 | 1,008 | 23,521 | 26,510 |
| Smelters, mines, and manufacturing industries | 4,122 | 2,069 | 69,107 | 75,298 |
| U. S. Army, Navy, and Coast Guard | 166 | 177 | [3] 8,792 | [3] 9,135 |
| Oil-company fuel [3] | 671 | 132 | [4] 42.121 | [4] 42.924 |
| Miscellaneous uses | 2,799 | 4,714 | 6,911 | 14,424 |
| Total | 91,959 | 22,204 | [3, 4] 325,159 | 439,322 |

[1] Bureau of Mines Minerals Yearbook 1939.

[2] See table 53 for break-down of this item into 6 grades.

[3] Includes 6,523,000 barrels of Navy-grade fuel oil.

[4] Includes 1,926,000 barrels of crude oil used as fuel.

## STILL GAS

Still gas is a major product of petroleum refining in point of quantity produced. In 1933 the volume of still gas recovered in United States refineries was 170,855 million cubic feet, which amounted to 45,212,000 barrels if reduced to the equivalent volume of oil on the basis of heating value. In 1938 the production was 236,943 million cubic feet, equivalent to 62,410,000 barrels of oil. This figure approximately equals the quantity of kerosene manufactured in 1938 and indicates that still gas is a large factor in refinery operations.

Production of still gas was less in 1938 than in 1937 and was the first time a decline from the previous year has been reported. The Bureau of Mines reports that 93 percent of the still gas produced in 1937 was burned as fuel in refineries; it supplied 47 percent of the total British thermal units (heat units) used in refineries in 1937.

## LUBRICANTS

The total quantity of lubricants manufactured in 1933 was 23,775,000 barrels, domestic demand was 17,152,000 barrels, and exports were 8.218,000 barrels. In 1938 production was 30,826,000 barrels, domestic demand was 21,248,000 barrels, and exports totaled 9,402,000 barrels. Table 55 segregates domestic demand for lubricants in 1932, 1933, 1937, and 1938. The table shows that more than 40 percent of the lubricants consumed in the United States is used in privately owned passenger automobiles. The industrial demand in 1938 almost equaled the demand for private passenger-car lubrication, and in 1937 it was larger. Lubricants used by trucks and busses comprised slightly more than one-eighth of the total domestic demand.

TABLE 55.—*Domestic demand for lubricants, 1932–33 and 1937–38* [1]

[Thousands of barrels of 42 gallons]

| Service | 1932 | 1933 | 1937 | 1938 [2] |
|---|---|---|---|---|
| Automotive: | | | | |
| Passenger cars | 8,780 | 8,516 | 10,115 | 9,924 |
| Trucks | 1,739 | 1,757 | 2,455 | 2,365 |
| Busses | 216 | 212 | 270 | 259 |
| Total automotive | 10,735 | 10,485 | 12,840 | 12,548 |
| Industrial | 5,879 | 6,667 | 10,483 | 8,700 |
| Total demand | 16,614 | 17,152 | 23,323 | 21,248 |

[1] Bureau of Mines Minerals Yearbook 1939, p. 998.
[2] Subject to revision.

### PARAFFIN WAX

The demand for paraffin wax in recent years is shown by the data in table 56 from statistics compiled by the Bureau of Mines.

These data show that the domestic demand for paraffin wax is subject to considerable fluctuations. The export demand has declined steadily, although the ratio of export demand to domestic demand still is higher than for any other petroleum product.

TABLE 56.—*Demand for paraffin wax*

[Thousands of pounds]

| Year | Domestic demand | Exports | Total demand |
|---|---|---|---|
| 1920 | 200,651 | 375,276 | 575,927 |
| 1930 | 242,109 | 292,973 | 535,082 |
| 1932 | 264,463 | 235,304 | 499.767 |
| 1933 | 353,243 | 247,769 | 601,012 |
| 1937 | 297,288 | 231,723 | 529,011 |
| 1938 | 278,060 | 201,919 | 479,979 |

### PETROLEUM COKE

Table 57 shows the extent of the decrease in production of petroleum coke in recent years despite the greater magnitude of refinery operations, particularly in cracking. Virtually all petroleum coke now is sold, with use as refinery fuel reduced to small proportions. It is notable, however, that the increased production in 1938 over that in 1937 went into storage, which indicates that the market is not very flexible but must be cultivated to the extent of the supply.

TABLE 57.—*Petroleum coke in 1932–33 and 1937–38* [1]

[Thousands of short tons]

| | 1932 | 1933 | 1937 | 1938 [2] |
|---|---|---|---|---|
| Production | 1,788.8 | 1,580.0 | 1,306.6 | 1,602.2 |
| Change in stocks | −181.4 | −602.8 | −10.8 | +328.9 |
| Total | 1,970.2 | 2,182.8 | 1,317.4 | 1,273.3 |
| Used as fuel in refineries | 333.0 | 263.0 | 84.0 | (3) |
| Other domestic demand | 1,547.8 | 1,729.4 | 1,069.1 | [4] 1,117.7 |
| Exports | 89.4 | 190.4 | 164.3 | 155.6 |
| Total | 1,970.2 | 2,182.8 | 1,317.4 | 1,273.3 |

[1] Bureau of Mines.
[2] Subject to revision.
[3] Not yet available.
[4] Includes coke burned as fuel in refineries.

### LIQUEFIED PETROLEUM GASES

Table 58 gives comparative data on sales of liquefied petroleum gases in 1932, 1933, 1937, and 1938. It is notable that the volume of sales in 1938 was nearly five times that in 1932. Since the Bureau of Mines began publishing statistics of sales of liquefied petroleum gases in 1922, sales each year have shown a marked increase over those of the previous year.

TABLE 58.—*Liquefied petroleum gases in 1932–33 and 1937–38* [1]

[Thousands of barrels of 42 gallons]

| Uses | 1932 | 1933 | 1937 | 1938 [2] |
|---|---|---|---|---|
| Domestic | 375.5 | 395.9 | 972.0 | 1,377.0 |
| Gas manufacturing | 230.8 | 198.0 | 266.0 | 294.9 |
| Industrial fuel | | | 1,031.2 | 925.0 |
| Chemical manufacturing | | | 637.9 | 769.0 |
| Internal-combustion-engine fuel | | | 404.4 | 498.0 |
| All other uses | 194.4 | 333.0 | 55.1 | 69.5 |
| Total | 800.7 | 926.9 | 3,366.6 | 3,933.4 |

[1] Bureau of Mines.
[2] Subject to revision.

## SECTION V. ALTERNATIVE FUELS

The question of alternative motor fuels from oil shale, coal, agricultural products, and other sources has been discussed at great length during the past 25 years or more. Although motor fuels have been obtained from these sources for many years, there can be little doubt that a greater expenditure in labor and material is involved than in manufacture of motor fuels from petroleum. In almost all instances of manufacture of motor fuels from these sources at present, the operation is aided by direct subsidy or by preference such as remission of taxes imposed on motor fuels.

The following discussion of the present status of production of motor fuel from coal has been written especially for this report.

## GASOLINE SUBSTITUTES FROM COAL

By A. C. FIELDNER,[33] J. D. DAVIS,[34] and H. H. STORCH [35]

### INDIRECT PROCESSES

There are two processes using coal as raw material in which motor fuel is a byproduct, namely, (1) the high-temperature carbonization of coal, including the gas- and coke-manufacturing industry, and (2) the low-temperature carbonization of coal.

1. In coke and gas works about 2.5 gallons of refined motor benzol can be obtained by the high-temperature carbonization of 1 ton of coal. On this basis, 176 million gallons of motor benzol could have been obtained from the total coal coked in byproduct ovens in the United States during 1937, or about 0.7 percent of the 24 billions of gallons of gasoline produced. If the entire output of about 440 million tons of bituminous coal in 1937 had been put through byproduct ovens the yield of motor benzol would have been only 1.1 billion gallons, or about 4.6 percent of the gasoline produced that year.

At present (1939) the production of coke is increasing rapidly because of the upward turn of the steel business, but it seems obvious that coke-oven light oil can never supply more than small portions of future motor-fuel requirements. Furthermore, it seems probable that increasing amounts of pure benzene and toluene will be required for the manufacture of explosives and other chemicals; it can be expected that a smaller proportion of the production will be utilized as fuel.

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[34] Chemist, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.
[35] Principal Physical Chemist, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.

2. Low-temperature carbonization is often cited as the process that will solve the problem of future motor-fuel supply. In this process coal is heated to 1,000° to 1,200° F. instead of 1,800° to 2,200° F., as in high-temperature carbonization. The tar yield is 20 to 35 gallons a ton or two to three times that obtained by high-temperature carbonization. Also the tar resembles petroleum in some respects. From 1 to 2 gallons of light oil can be scrubbed from the gas, and another gallon or two distilled from the tar, the total yield being 2 to 4 gallons.

Refining losses would bring the net yield of motor fuel from gas scrubbing and straight distillation of the tar to about 2.5 gallons a ton, or about the same as is obtained in high-temperature carbonization. However, this low-temperature tar may be subjected to the same pressure-cracking processes that are used for petroleum, and thus yield 20 to 30 percent of motor fuel. It is, therefore, reasonable to assume a possible yield of 7 to 12 gallons per ton of coal carbonized at temperatures of 450° to 700° C. (840° to 1,290° F.).

If 100 million tons of bituminous coal, about one-fourth of the output in 1937, had been carbonized at low temperature, the motor-fuel yield on the basis of 10 gallons to the ton would have been 1,000 million gallons, or about 4 percent of the gasoline production in that year. It is evident that the maximum probable development of low-temperature carbonization, while furnishing a material quantity of motor fuel, cannot satisfy the entire demand. We must turn to other processes in which motor fuel is the principal product rather than a byproduct.

### DIRECT PROCESSES

Two direct processes for the production of motor fuel from coal have been developed. They are:

(1) The hydrogenation and liquefaction of coal by the modified Bergius process which produces gasoline, Diesel fuel, and fuel oil. The I. G. Farbenindustrie A. G. of Germany developed this process.

(2) The complete gasification of coal and catalytic conversion at atmospheric pressures of the resulting mixture of hydrogen and carbon monoxide into gasoline, Diesel fuel, lubricating and fuel oils, and paraffin wax. This is known as the Fischer-Tropsch process. The use of higher pressures (about 200 atmospheres) and appropriate catalysts results in the production of methanol and higher alcohols from the same gas mixture.

### COAL HYDROGENATION PROCESS

In the modified Bergius process a coal-oil-catalyst mixture containing 40 to 50 percent of powdered coal and 0.1 to 1 percent of a powered catalyst is forced into a high pressure vessel with hydrogen gas at over 200 atmospheres pressure and at about 860° F. After about 2 hours' contact time the coal is liquefied, and the oil product is separated into gasoline, middle oil, and heavy oil. The latter is recycled so as to provide oil for mixing with coal at the start of the process. The middle oil is hydrogenated further using a catalyst held in place in the converter rather than pumped in along with the raw material. The final products are gasoline and Diesel fuel. About 50 percent of the coal that is hydrogenated is obtained as a motor fuel and about 5 tons of coal is necessary per ton of gasoline produced, to provide coal for all purposes including power, steam, etc.

Germany is reported to have produced, in 1938, 900,000 metric tons of gasoline by direct hydrogenation of tar, coal, and lignite,[36] or about 50 percent of the total gasoline consumption.[37] The total ultimate annual capacity when all plants under construction are completed is estimated at nearly 2 million tons.

In Great Britain the Imperial Chemical Industries plant at Billingham produced about 140,000 tons (42 million imperial gallons in 1938.[38]

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[36] Pier, M.: Chem. Trade Jour., vol. 102, 1938, p. 494. Colliery Guardian, Germany's Four-Year Plan; vol. 157, 1938, pp. 683–684.

[37] Carr, T. P., Proportion of Substitute Fuels in Germany: Gas World, vol. 109, 1938, p. 14.

[38] The Institution of Mining Engineers, Utilization of Coal Committee Summary of Progress No. 13, p. 2, June 30, 1939.

Production of synthetic motor fuel from coal in countries other than Germany and Great Britain is of the order of 10 percent of the Billingham output. In Japan, however, there is some indication of rapid expansion in the near future.[39]

### SYNTHETIC GASOLINE FROM WATER GAS

In the Fischer-Tropsch process developed by Dr. F. Fischer in Germany since 1926, the raw material is a mixture of hydrogen and carbon monoxide gases produced from coal or coke and steam. This gas mixture, after purification to remove virtually all sulfur compounds is passed over a solid catalyst such as a mixture of cobalt and thoria with diatomaceous earth. The temperature is maintained at 356 to 410° F. and the pressure between 1 and 50 atmospheres. The valuable products are propane, butane, gasoline, Diesel fuel, and paraffin wax. About 4 to 5 tons of coal is necessary per ton of products. The cost of production probably is in the same range as that for direct coal hydrogenation.

In recent years the Fischer-Tropsch process has been developed rapidly in Germany. Four plants with a total yearly capacity of 300,000 tons of gasoline have been operating during the past 2 years, and five more plants under construction will raise the annual capacity up to a total of 525,000 tons.[40] The total production of gasoline during 1938 was reported to be 100,000 tons by this process.[36]

The process can be installed at gas plants in relatively small units, whereas the coal hydrogenation process requires a large capacity plant for economical operation.

### ESTIMATED COSTS OF PRODUCTION

The best available estimates on the cost of production of synthetic gasoline either by coal hydrogenation or by synthesis from water gas are given in the reports [41] of the Committee of Imperial Defense of Great Britain and the Labor Party of England.

The estimated total costs of production discussed in these reports range from 12 to 25 cents per United States gallon, the spread being due principally to various rates of amortization of the plant and secondarily to the cost of the coal. The Imperial Defense Committee concludes that the cost for a new plant would range from 15.6 cents to 19 cents per United States gallon. (Conversion figures to United States units taken from Egloff's article.) [42] The corresponding estimate of the British Labor Party is 18 cents per United States gallon. Egloff [42] concludes that, on the basis of all sources of information, the cost per United States gallon of motor fuel produced by either coal or carbon monoxide hydrogenation is about 18 cents, and that for American conditions with lower cost of coal and improvement of manufacturing technique the cost would be less than 16 cents per gallon.

### HYDROGENATION OF AMERICAN COALS

In the United States the Bureau of Mines has erected an experimental coal hydrogenation plant whose capacity is about 100 pounds of coal per 24 hours. The plant is so designed that with comparatively little additional equipment the Fischer-Tropsch process could also be studied. The main objective of the plant's operations thus far has been to study the hydrogenation of coals from the more important coal beds of the United States. Seven coals have been assayed. The assay consists in determining the maximum quantity of an oil containing 20 percent of gasoline and 80 percent of oils boiling below 650° F., which can be produced in a single pass through one converter. The following table contains the assay data on seven coals ranging in rank from a medium volatile bituminous coal to lignite:

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[39] Iron and Coal Trade Review, vol. 135, 1937, p. 716. Oel u. Kohle, vol. 14, 1938, pp. 83–85.

[40] Wilke, G., The Production and Purification of Gas for the Synthesis of Benzine: Che. Fabrik., 1938, pp. 563–568.

[41] Subcommittee on Oil from Coal (Viscount Falmouth, chairman), Committee of Imperial Defense. H. M. S. Office, London, February 1938, 71 pp.

Labor's Plan for Oil from Coal. Published by the Labor Party (London) June 1938.

(Both reports are reviewed by Gustav Egloff, see reference 42.)

[42] Egloff, Gustav, Motor Fuel Economy of Europe: Ind. Eng. Chem., vol. 30, 1938, pp. 1091–1104.

*Hydrogenation assay of some United States coals*

| Coal bed | State | Rank | Total oil yields, percent of | | | Hydrogen consumption, percent of a. m. f. coal | Tar acids, yield in percent of a. m. f. coal | Tar bases, yield in percent of a. m. f. coal |
|---|---|---|---|---|---|---|---|---|
| | | | a. m. f. coal | Dry coal | Coal as mined | | | |
| Mary Lee | Alabama | Bituminous, M. V. "A" | 59.8 | 54.1 | 51.7 | 8.5 | 7.4 | 2.3 |
| Pittsburgh | Pennsylvania | Bituminous H. V. "A" | 70.5 | 65.2 | 65.1 | 9.0 | 11.1 | 2.8 |
| No. 6 | Illinois | Bituminous, H. V. "B" | 70.5 | 65.4 | 60.4 | 8.5 | 11.4 | 1.6 |
| McKay | Washington | Bituminous, H. V. "C" | 68.5 | 65.7 | 59.3 | 7.6 | 13.0 | 3.2 |
| Puritan mine | Colorado | Sub-bituminous "A" | 63.0 | 59.3 | 48.9 | 9.7 | 12.2 | 2.6 |
| Monarch No. 45 | Wyoming | Sub-bituminous "B" | 66.5 | 63.1 | 48.5 | 8.5 | 14.5 | 2.9 |
| Fort Union | North Dakota | Lignite | 54.0 | 47.0 | 29.0 | 8.0 | 11.4 | 1.3 |

NOTE.—M. V.=medium volatile; H. V.=high volatile; "A," "B," "C" are classifications of rank in decreasing series; a. m. f.=ash-and-moisture-free.

Several interesting conclusions may be drawn from the data of the above table. Excepting the Mary Lee coal and the lignite the yields of oil do not change much with rank, when the comparison is made for the dry coals. For the coals as mined it should be stated that the low rank coals which comprise 50 percent of the national coal reserves, contain large amounts of water and this explains the rapid decrease in oil yield with decreasing rank of coal. The hydrogen consumed on a dry, ash-free basis does not show any trend with coal rank and is the same (within 10 percent of its value) for all of the coals. This fact is explained by the progressively larger amounts of oxygen eliminated as carbon dioxide with decreasing rank. The yields of tar acids and tar bases are about 100 times those obtained in coal carbonization. The tar acids (phenol, cresols, xylenols) are of commercial value as raw materials for the plastics industries, and the tar bases serve as raw materials in several organic chemical processes. The bulk of the oils obtained in the coal assay is aromatic in nature and could be utilized as solvents and as raw material for the production of benzol and toluene for explosives manufacture. The possibilities of coal hydrogenation as a source of organic chemicals is apparent, and the demand for such chemicals is large, particularly in the rapidly growing plastics industry. The average selling price of these raw materials should be about 20 cents per gallon (or about 2 cents per pound). The cost of production should be lower than that of gasoline because the second stage of hydrogenation is not needed.

Careful appraisal of the present technical and economic status of processes for obtaining gasoline and Diesel fuel from coal leads to the conclusion that both the coal hydrogenation and the water-gas synthesis processes are available for large-scale development under American conditions to supplement any future diminishing supply of petroleum fuels that may occur. Neither high- nor low-temperature carbonization of coal can be expanded enough in capacity so as to furnish any large contribution of liquid fuel. The light oils and tars from these processes are byproducts, and total plant capacity is determined by the demand for the main products of coke and gas.

Five years ago the coal hydrogenation process appeared superior to the water-gas synthesis process on the basis of cost and commercial developments. But at present both processes are operating on a large scale in Germany, and the costs are said to be of the same order, approximately 18 cents per United States gallon. This cost is far above the present American cost of petroleum gasoline at the refinery. There is little doubt that when the time comes for the production of gasoline from coal, American costs may be as low as 12 cents per gallon if the program of research and development applied to this problem is as intensive as that conducted on the manufacture of gasoline from petroleum. However, that cost is more than twice the present price of gasoline at the refinery. The labor and equipment required for making gasoline from coal greatly exceed those necessary for manufacture of gasoline from petroleum and, what is more important, much energy is lost in the process of conversion.

In round numbers, 4 to 5 tons of coal are consumed in making one ton of gasoline and only 40 to 45 percent of the original heat units in the coal used remains in the resulting motor fuel.

The United States does have large resources of coal. The reserves of coal, exclusive of anthracite, are estimated at 3½ trillion tons. It is believed that 1⅓ times our present annual production of coal would be needed to yield our present annual requirements of gasoline. Such increase of our coal consumption would no doubt solve the immediate problem of the coal industry, but at a greater consumption of national fuel resources. A forward-looking national fuel policy would seek to delay the day of making gasoline from coal as long as possible by reserving the higher-value fuels of natural gas and petroleum for those uses that cannot be met so efficiently by the direct combustion of coal.

### TIME REQUIRED TO PUT HYDROGENATION ON A COMMERCIAL BASIS

It must be emphasized that the industrial plants obtaining gasoline from coal in England, France, Japan, and Germany are not, in a strict sense, on a commercial basis. Large subsidies in the form of tariffs or excise taxes on petroleum or gasoline from petroleum are required to make their operation commercially possible. None of these countries has any important home sources of petroleum, but they do have extensive coal deposits. In case of war and blockade, the production of motor fuel from coal would be of the greatest importance to these countries. The large internal petroleum resources of the United States, if properly conserved, will defer this war need of converting coal, certainly for one and possibly three or more decades.

Large-scale hydrogenation of coal in the United States would require an extended period of research on our particular coals to determine which coals would give the best yields and which locations would prove most economically desirable.

In conclusion, it is now proved that technical processes for making gasoline or motor-fuel substitutes from coal are available, if and when a failing supply of petroleum requires this step. But the product will be made with the sacrifice of much more of the original fuel energy than is lost in making gasoline from petroleum. Furthermore, the cost of the gasoline to the consumer will be materially higher.

## PETROLEUM SUBSTITUTES FROM OIL SHALES

There has been no important change in the oil-shale situation in the United States since the 1934 report was written. A noteworthy development, however, is the increased availability of information in English regarding shale-oil characteristics and practices in oil-shale utilization in foreign countries, as a result of the conference on oil shale and cannel coal organized by the Institute of Petroleum (British) and held in Scotland June 6–10, 1938. The compendium of papers presented to the conference, published in book form,[43] "records the technical achievements and possibilities of a modest though, in modern conditions, important industry."[44] Moreover, the report of the Energy Resources Committee includes a chapter by Hopper[45] that gives a good review of oil shale as well as other sources of liquid fuel in foreign countries. The following discussion is based largely on these two sources.

### OIL-SHALE INDUSTRIES IN FOREIGN COUNTRIES

The oil-shale industries in Scotland and in other countries often are cited as examples to indicate the possibilities for an oil-shale industry in the United States. The fact frequently is overlooked, however, that conditions in those countries were and are different from those in the United States. Thus, oil-shale utilization has been practiced on a commercial scale only in countries that have no indigenous supply of petroleum or at most only enough to satisfy a minor fraction of the domestic demand for motor fuel. Even in those countries

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[43] Oil Shale and Cannel Coal, Proceedings of a Conference held in Scotland, June 1938. Published by the Institute of Petroleum, London, 1938.

[44] Harry Crookshank, M. P. Secretary for Mines, Foreword: Work cited in footnote 43.

[45] Hopper, Paul H., Foreign Experience in the Use of Substitute and Synthetic Motor Fuels: Work cited in footnote 28, pp. 317–332.

where an oil-shale industry has been in existence, it has been operated under substantial subsidies in the form of remission of taxes and other preferential consideration, as well as heavy import duties on imported motor fuel and on crude petroleum imported for refining.

### BRITISH EMPIRE

*Scotland.*—At present the largest shale-oil industry in the world is in Scotland. The most successful technique for producing shale oil has been developed there since 1850 or has grown out of experience gained in those operations. The Scottish oil-shale industry achieved its maximum output in 1913 when 3.5 million tons of shale was retorted. In 1937 the input was 1,432,000 tons. In that year 1 ton of shale on the average yielded 26.5 United States gallons of crude oil. Although gasoline made from shale oil in the British Isles received a preference in the form of remission of import duty and taxes equivalent to 14.9 cents per United States gallon, only one-half of 1 percent of the demand for motor fuel in the United Kingdom in 1937 was supplied from shale, with petroleum supplying 93.1 percent, benzol 3.5 percent, and gasoline from coal most of the remaining 2.7 percent.

*Australia.*—Despite financial disastrous results of attempts during the past 30 years to extract oil commercially from the Newnes shales of New South Wales, the Commonwealth and New South Wales Governments have announced that they will contribute $2,500,000, secured by 4½ percent debentures, to supplement $830,000 to be invested by private interests in Sydney to develop a shale-oil industry. The project is to have complete remission of excise duty for 25 years as well as further assistance in the forms of a concession in railway freight rates and preferential consideration in placing Government orders for motor spirit.

Sizable deposits of shale rich in oil occur, the average yield being about 120 United States gallons per ton. After several investigations by experts it was concluded in 1937 that enough progress had been made in the technique of processing oil shale to warrant further efforts to work the deposits at Newnes. The new company purposes to begin operations on January 1, 1940, with an output of 10,000,000 imperial gallons (286,000 barrels) of petrol per annum.

*Canada.*—Occurrences of bituminous shales have been known in Canada for many years. In 1859 near Collingwood, Ontario, and again in 1862 near Rosevale, New Brunswick, attempts to retort local shales temporarily met with a fair degree of success. Both attempts were abandoned owing to the rapidly increasing production of petroleum from newly discovered pools of western Ontario and Pennsylvania. Except during a comparatively brief period in the 1860's, Canada has depended largely on foreign sources for its supply of crude petroleum and petroleum products.

Deposits of oil shale have been found in the Provinces of Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, and British Columbia and in the districts of Mackenzie and Franklin.

Swinnerton [46] reports that three processes have been tried on a small scale, and in addition plants on a semicommercial scale have been erected by four companies in Canada. Pressure-cracking tests also were conducted on samples of crude shale oil from New Brunswick shale in the laboratories of two United States companies.

There is no oil-shale industry in Canada at present, and past activities have been confined mainly to field exploration and laboratory studies. Enough development work has not yet been done to determine the oil-shale reserves in even the most favorably situated deposits. The small experimental plants built between 1920 and 1930 did not operate long enough to enable reliable estimates to be made of the cost of mining the shale used or to ascertain the suitability of the different retorts tested.

### ESTONIA

According to Kogerman,[47] the Estonian oil-bearing mineral known as "kukersite" was discovered about 150 years ago, but its exploitation as a substitute for coal and for production of illuminating gas was begun only during the World War. Production of shale oil was started on an experimental scale in 1919, and

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[46] Swinnerton, A. A., Oil Shales of Canada, pp. 216–226: Work cited in footnote 43.

[47] Kogerman, P. N., Hundred Years of the Chemical Investigation of an Oil Shale: Work cited in footnote 43, pp. 115–123.

after a few years commercial-scale development commenced. In 1937 the production of shale oil reached 109,358 tons. Hopper[48] estimates that 56.5 percent of the demand for motor fuel in Estonia in 1937 was supplied by gasoline from shale and that 45,000 barrels of a total production of 122,000 barrels of shale gasoline was exported and 378,000 barrels of crude shale oil was shipped, mainly to nearby countries. Luts[49] states that in 1937 a total of 525,599 tons of shale was used directly as fuel and 589,261 tons for the production of oil.

Motor fuel made from oil shale in Estonia is sold in the domestic market at the same retail price as imported gasoline, but the manufacturers are aided by an import duty equivalent to 8 cents per United States gallon and are not required to pay an internal tax equivalent to 13 cents per United States gallon. Thus the retail price of gasoline in Estonia (37 cents per United States gallon) includes 21 cents in taxes if the gasoline is imported and the same amount in subsidy if the gasoline is made from oil shale or other indigenous material. No definite information is available to indicate what factors influence the Estonian oil-shale industry to sell oil in foreign markets in competition with petroleum.

### JAPAN

According to O'Hashi and Fukuzawa,[50] the oil-shale industry in Fushun was started because of the necessity of removing the shale overburden from the Fushun colliery, which is worked on the open-cut system. With the expense of removing the shale charged to the coal-mining operations, the oil-shale retorting and refining operations are said to be self-supporting. The yield ranges from 2 to 12 percent of the shale, the average being about 5 to 6 percent. The deposit covers 11 square miles and is about 450 feet thick, with a total quantity estimated at 540 million tons of shale.

The retort used is similar to that employed in Estonia. In 1929 a plant was erected at Fushun with a reported annual capacity of 1,360,000 metric tons of shale, corresponding to 70,000 tons of oil. Additional retorts and a cracking unit erected since 1934 have increased the throughput and raised the octane rating of the gasoline produced. The production of about 150,000 tons of oil per year approximately equals the quantity of shale oil produced in Scotland in 1937. Further increase in this capacity is contemplated.

From the point of view of quantity of shale treated, therefore, this is one of the largest oil-shale enterprises in the world. Furthermore, it is responsible for a good share of the total home production of crude oil in the Japanese Empire.

### FRANCE

Siegler[51] states that the oil-shale industry in France dates back to about 1838, compared with the date of the first plant built by Young in Scotland in 1845. The industry is a small one, despite the exemption from duty and internal fiscal taxes of 1.56 fr. per liter (6 fr. per United States gallon). Pumpherston (Scottish) retorts are used. The quantity of shale mined in 1937 was 129,400 tons. The yield of crude shale oil plus naphtha extracted from the retort gases at Autun in 1937 was 22.8 United States gallons per ton of shale. The crude shale oil is cracked, forming three products—cracked distillate, gases, and coke. The coke amounts to 17 percent of the weight of the oil entering the cracking apparatus. After cracking and refining the yield of marketable motor fuel is about the equivalent of 13.4 United States gallons per ton of crushed shale.

### SWEDEN

According to Bergh,[52] Sweden has very large deposits of oil shale belonging to the Cambrian-Silurian period. In the middle and southern parts of the country, close to rail and waterways, about 5,000 million tons of shale are to be found. Some 630 million tons of this shale, in seams about 30 feet thick and representing approximately 32 million tons of shale oil, may be mined cheaply in open-cuts.

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[48] Hopper, Paul H., Work cited in footnote 28.

[49] Luts, K., The Occurrence and Application of Kukersite in Estonia, with particular reference to the Plant of the First Estonian Oil-Shale Industry: Work cited in footnote 43, pp. 124–143.

[50] O'Hashi, T., and Fukuzawa, T., The Development of the Shale-Oil Industry in Manchuria: Work cited in footnote 43, pp. 267–271.

[51] Siegler, J., The Bituminous-Shale Industry in France: Work cited in footnote 43, pp. 248–255.

[52] Bergh, Sven V., Shale-Oil Production in Sweden: Work cited in footnote 43, pp. 256–266.

The retorting plant, erected in 1925, was specially designed to meet Swedish conditions. It is owned by the Swedish State, under administration of the Naval Board, and was the only one running in 1938. The plant has a daily throughput capacity of about 75 tons of shale. The oil is of asphaltic type, and the yield is about 4 percent by weight of shale. Besides the oil, a gas of high heating value is obtained in retorting and is used to burn limestone in a limekiln. Because the lime is used exclusively in agriculture, the limekiln is run only from March through September, and during the remainder of the year the oil-shale plant is shut down. It is planned to provide other means of using the gas, and the retorting plant also is to be enlarged.

The crude shale oil is separated by distillation into three fractions—light, medium, and heavy. The light oil is used in Hesselman-type (spark-plug) engines, the medium oil in Diesel engines, and the heavy oil as boiler fuel. Cracking has been done only on an experimental scale. In this connection, the following remarks of A. E. Dunstan, chief chemist, Anglo-Iranian Oil Co., Ltd., London, are of interest:[53]

"It is absolutely necessary to develop a new technique for shale oils. It cannot merely be assumed that shale oil follows petroleum. Production of gasoline is uneconomic. New developments are being undertaken, as, for example, the use of shale distillate as Diesel fuel. Still more important is the complete gasification of waste shale, etc., e. g., into olefins and tertiary carbon groups which combine to give iso-octane with no hydrogenation, and even $CH_4$ can be liquefied into a liquid fuel of high octane value."

## OIL SHALE IN THE UNITED STATES

The enormous deposits of oil shale in various sections of the United States often are mentioned as possible future sources of motor fuel and fuel oil. These deposits have been divided into three general classes: (1) Oil shale of the Rocky Mountain region, (2) Devonian black shale of the Eastern States, and (3) cannel shale of the Eastern States.

Experimental work has shown that these oil-shale deposits can be made to yield quantities of crude shale oil[54] adequate to supply our requirements for motor fuel and fuel oil for many years, and this oil can be used directly as boiler fuel.[55] The crude shale oil can be converted into motor fuel by cracking and chemical treatment.

In the fuel economy of the United States oil from shales remains in the category of a reserve for future needs. In fact, shale oil never has been produced in this country in quantities approximating those apparently necessary to establish oil-shale utilization as a sustained industry. The total output of shale oil has been insignificant in relation to demands for liquid fuels. Inquiries by the Bureau of Mines indicate that there has been no production of shale oil in this country since the Bureau's experimental plant was closed in June 1929.

It does not seem likely that shale oil will compete with petroleum in the United States in the near future; more probably use of oil shale as a source of substitutes for petroleum will develop gradually when and where conditions favor its use instead of petroleum. During this development period problems of a technologic and economic character will be encountered and surmounted, and when or if the time comes that shale oil will be required to provide quantities of petroleum substitutes comparable to our present consumption of petroleum, productive capacity will have reached that magnitude gradually.

In this connection it is somewhat reassuring to reflect that in addition to the long life of the oil-shale industry in Scotland, utilization of oil shale is in process of development in other countries, including Estonia, Australia, and Japan, where competition with petroleum is not a serious factor. Experience in technologic development gained in those countries will be helpful when or if the United States shall need to supplement or replace petroleum as a source of liquid fuel. Although the oil shales found there are not entirely analogous to oil shales of the United States, it seems likely that some part of the experience gained will be

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[53] Work cited in footnote 43, p. 392; discussion.

[54] Gavin, M. J., and Desmond, J. S., Construction and Operation of the Bureau of Mines Experimental Oil-Shale plant: Bureau of Mines Bull. 315, 1930, 154 pp., and unpublished data in files of the Bureau of Mines.

[55] U. S. Naval Boiler Laboratory, Philadelphia Navy Yard: Tests of Shale Oil Produced by Bureau of Mines at Rulison, Colo. Evaporative Efficiency Runs with 5 Types of Fuel-Oil Burners: Rept. 1075, September 2, 1932.

helpful in attacking the problem of utilizing oil shales of the United States. The oil-shale situation in the United States has been treated in more detail by Kraemer.[56]

## MOTOR FUELS FROM ALCOHOL

During the past 5 years interest in alcohol from agricultural sources as a constituent of automobile fuel has been maintained, owing to various proposals for promoting this use of alcohol as a measure of aid to agriculture. The following excerpts from a report by Jacobs[57] give a brief summary of the history and the essential features of the subject:

"In the United States the idea of using alcohol from farm crops as a motor fuel is not new. In 1907 the Department of Agriculture published bulletins relating to the possible use of alcohol in internal-combustion engines as then designed, and the Iowa Agricultural Experiment Station also did some work along this line. In 1909 the Geological Survey published (a report) on the same subject. The Bureau of Mines reported on it in 1911 and 1912. The Department of Agriculture also experimented with a small distillery for the production of industrial alcohol from farm crops (1910).

"Little progress toward use of alcohol fuel was made, however, until the low-crop years of 1931–32, when because of the large surplus of unsalable grains and the low income on farms, the idea of using alcohol from farm crops as a motor fuel was again advanced.

"In 1933 road tests of alcohol fuels were made by the National Bureau of Standards in cooperation with automotive groups. Similar road tests were made at the Iowa State College, where a series of studies was made on various aspects of the problem because of the surplus corn in Iowa. The Chemical Foundation became interested in alcohol motor fuel about 1935, and this resulted in the establishment of a trial production plant at Atchison, Kans. Recently the operations of this plant, particularly in the merchandising of alcohol motor fuels, have created widespread interest in the Middle West, which has resulted in proposals to erect similar plants at other points in the Mississippi Valley. The State of Idaho is erecting a pilot plant at Idaho Falls for study of alcohol production from cull potatoes. In the past few years the large amount of data published on the subject has resulted in partially clarifying controversial points. Legislation designed to advance the use of alcohol motor fuels has been introduced in various State legislatures and in Congress, but thus far has failed of passage except in the State of Nebraska, where the State gasoline tax is remitted on the alcohol portion of a blended fuel.

"To evaluate the economic possibility of making motor fuel from agricultural products it is necessary to know first the amount of suitable raw material that is now available or could probably be made available later. The possibility of increasing acre yields and decreasing crop-raising costs should be studied. The distribution of the crops and the problems of harvesting, collecting, transporting, and storing without serious deterioration should be considered, especially in the case of perishable materials. Technical problems of processing the materials and refining the products would have to be solved. The net price that could be paid for the raw material, its value in comparison with other available raw materials, the cost of producing the alcohol, and the selling price such a product could command on the basis of comparative efficiency as motor fuel are essential factors in the undertaking and should be looked at realistically.

"In addition, the production of motor fuel from agricultural products would present social, legal, and economic aspects, and their various interrelationships should be carefully considered. Above all, it must be remembered that the situation is continually changing and that consideration of the problem should include future as well as present conditions."

Dr. Jacobs also has contributed a chapter to the report of the Energy Resources Committee[58] dealing with motor fuels from agricultural products with reference to the United States. In the same report[59] Hopper gives a résumé of foreign experience with motor-fuel blends, including alcohol.

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[56] Kraemer, A. J., Oil Shale and Shale Oil: A Brief Review of Work by the United States Bureau of Mines: Work cited in footnote 43, pp. 227–247.

[57] Jacobs, P. Burke, Motor Fuels From Farm Products: U. S. Department of Agriculture Misc. Pub. 327, Devember 1938, 129 pp.

[58] Jacobs, P. Burke, Motor Fuels From Agricultural Products: Work cited in footnote 28, pp. 332–37.

[59] Hopper, Paul L., Foreign Experience in the Use of Substitute and Synthetic Motor Fuels: Work cited in footnote 28, pp. 317–332.

Hearings before a subcommittee of the Committee on Finance, United States Senate,[60] brought forth testimony from a variety of sources, including individuals and organizations favorable and opposed to the proposals embodied in the bills.

These sources of information on use of alcohol or other nonpetroleum materials as motor fuel, as well as the references given therein to sources of additional information, emphasize the great variety of aspects involved in adequate consideration of the subject. The reports by Jacobs and by Hopper are concise discussions that cannot well be condensed further for the purposes of this report in justice to the authors and to the subject. Consequently, readers are referred to the reports mentioned above and to current sources of information for knowledge of the latest developments in this field.

Mr. Cole. We will recess until 2 o'clock.

(Thereupon the subcommittee took a recess at 12:20 p. m. until 2 p. m. of the same day.)

### AFTER RECESS

The subcommittee reassembled, pursuant to the taking of recess, at 2 p. m.

Mr. Cole. The committee will please come to order.

## STATEMENT OF ARNO C. FIELDNER, CHIEF OF THE TECHNOLOGIC BRANCH, AND CHIEF ENGINEER, COAL DIVISION, BUREAU OF MINES, DEPARTMENT OF THE INTERIOR

Mr. Cole. Mr. Fieldner, will you please state your full name, where you are employed at the present time, and your experience, training, and what part of this work you have been associated with, and any preliminary statement you want to make.

Mr. Fieldner. My name is Arno C. Fieldner. I am Chief of the Technologic Branch and Chief Engineer of the Coal Division of the Bureau of Mines.

I am a graduate of the Ohio State University in chemical engineering.

The material which I am presenting has to do with gasoline substitutes from coal; the possibilities of making a synthetic gasoline from coal. It has been prepared in collaboration with two of my associates, Mr. J. D. Davis, chemist in charge of the Coal Carbonization Section of the Bureau of Mines, Pittsburgh station, and Dr. H. H. Storch, chemist in charge of coal hydrogenation research at that station.

This report covers the possibility of obtaining gasoline substitutes as a by-product from the normal process of making gas and coke, and also the present status abroad in making synthetic gasoline by the hydrogenation and liquefaction of coal in which oil and gasoline are the principal products, and not by-products; and also a second synthetic process known as the Fischer-Tropsch process.

In the standard methods of making coke and gas, about two and one-half gallons of refined motor benzol is obtained from each ton of coal carbonized, and this motor benzol is used as a blending agent with gasoline, or it can be used by itself; but the total amount

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[60] Use of Alcohol From Farm Products in Motor Fuel: Hearings before a subcommittee of the Committee on Finance, United States Senate, Seventy-Sixth Congress, First Session, on S. 552, A Bill to Provide that Gasoline Mixed with 7 Per Centum of Ethyl Alcohol Shall Not be Subject to the Tax Imposed by Section 617 of the Revenue Act of 1932, as Amended and An Amendment Intended to be Proposed to an Appropriate House Revenue Bill to Provide that Gasoline Mixed with 10 Per Centum of Ethyl Alcohol shall not be Subject to the Tax Imposed by Law, May 23, 24, 25, and 29, 1939.

obtainable in the United States, if all of the light oil obtained from coking coal where used for motor fuel, is very small. Only about 176 million gallons could have been obtained in the year 1937, or about 0.7 percent of the gasoline produced during the year. Even if all of our bituminous coal production of 440,000,000 tons had been coked before using it, it would have amounted to only 4 or 5 percent of the gasoline produced in 1937.

Mr. Cole. What was that figure?

Mr. Fieldner. Four to 5 percent. That is about 1.1 billion gallons. Therefore, we could not look forward to these by-product oils obtained in the normal gas and coke-making processes, to replace any material percentage of our petroleum gasoline requirements.

Mr. Cole. Can you give me a practical application of that, to support your statement? Can you tell me about the countries where it has been tried?

Mr. Fieldner. Of the synthetic processes?

Mr. Cole. Yes.

Motor benzol cannot supply more than a negligible percentage of our gasoline requirements.

If in the future we wish to get material amounts of gasoline from coal, we must turn to one of the two oil-from-coal processes that have been developed in Germany. The first one to be operated on a commercial scale is the hydrogenation and liquefaction of coal by the Bergius—I. G.—process. It produces a crude oil similar to petroleum which can be refined by analogous methods, producing gasoline, Diesel oil, or fuel oil. In this process a paste of about equal parts powdered coal and oil (oil made from the coal) is subjected to a pressure of about 3,000 pounds to the square inch, and a temperature of about 800° Fahrenheit, in an atmosphere of hydrogen and in the presence of a catalyst. Hydrogen gas is pumped with the paste into pressure cylinders, and under these conditions the hydrogen is forced into the molecular structure of the coal so that it takes on the same or similar chemical composition to that of oil. Some gas also is produced.

This method has been developed in Germany and several plants are in operation.

Mr. Kelly. Is it a very expensive process?

Mr. Fieldner. Yes, sir; it is an expensive process. I will come to some estimate of costs a little later.

In Germany it is estimated, as nearly as we can gather from technical publications, that in the year 1938 they produced about 900,000 metric tons of gasoline by this process, probably close to 50 percent of their gasoline consumption. And in Great Britain, Imperial Chemical Industries, Ltd., has one large plant which has a capacity of 140,000 tons of gasoline per annum.

In Germany there has been developed a second process known as the Fischer-Tropsch process, in which the gases carbon monoxide and hydrogen, which are both made from either coal or coke are caused to react with each other in the presence of certain chemicals to produce gasoline and Diesel oil.

This process operates at atmospheric pressure and can be operated in smaller units than the Bergius process. Not as large a plant is required for economical operation. Germany has a number of these plants in operation. It is estimated that they have a total annual capacity of about 500,000 tons of gasoline.

Now, as to the cost, the best available estimates on the cost of production of synthetic gasoline by either coal hydrogenation or synthesis from carbon monoxide and hydrogen are given in a report of the Committee of Imperial Defense of Great Britain. This is commonly known as the Falmouth committee, named after the chairman.

Converting their figures into United States gallons, and cents, the costs of production discussed in this report range from 12 to 25 cents per United States gallon. That is production at the plant. The spread being due primarily to the various rates of amortizing the plant and to the cost of the coal.

This committee concludes that if a new plant were built in England, the production cost of gasoline would range from about 16 to 19 cents per United States gallon; and a report published by the Labor Party in England is also in the same neighborhood.

Taking all of these cost estimates into consideration, it appears to us that about the best figure to take at the present time for either of these two processes would be about 18 cents per United States gallon, and that if we built plants in America and considered our lower coal costs, and perhaps improvement in manufacturing technique, we might bring it down to 16 cents a gallon, and perhaps in the distant future if we put a great deal of research on it, intensive research, such as has been put on refining oil, there is a possibility of a cost as low as 12 cents a gallon. But, for present conditions an estimate of around 18 cents is probably the best we can give from the information available.

We have done some research at our Bureau of Mines station at Pittsburgh on the possibilities of liquefying American coals, and we find that practically all of them can be liquefied under appropriate conditions, and that the yields obtained vary from about 47 percent by weight of crude oil from a ton of coal, to a maximum of about 65 percent; this 47 percent being for lignite. That is a low-rank coal, of course. Additional coal is required for the production of hydrogen heat and power used in the process a total of 4 to 5 tons of coal are required for producing 1 ton of gasoline.

When the time comes there is no question but what liquid fuel can be made from our American coals, and with further research, we probably could bring the cost down below the present figures.

As to the suitability of these two processes: So far as we know they are practically equal in their possibilities. The Fischer process is more suitable for small-scale plants. The hydrogenation process in very large-scale plants may be the cheaper.

We have large resources of coal and all of our coal, except probably our anthracite, might be considered as suitable for liquefaction via the Bergius process, and even our anthracite could be used in the Fischer process by making water gas from the anthracite.

Any of our coals are possible sources of motor fuels; but the cost is considerably above the cost of making gasoline from petroleum; probably three or four times as much at the present time.

That, Mr. Chairman, is the substance of the report which we have prepared. The complete report is included in the report filed by Mr. Kraemer.

Mr. **Cole.** Thank you, Mr. Fieldner. Is that the entire report?

Mr. **Fieldner.** That is the entire report.

Mr. **Cole.** I understood you to say that Mr. Storch assisted you in this work.

Mr. **Fieldner.** Yes, sir.

Mr. **Cole.** Is Mr. Storch present?

Mr. **Fieldner.** No, sir; he is not here; but we collaborated in the preparation of this report.

Mr. **Cole.** Is Mr. Thorne, who assisted Mr. Kraemer in preparing his report in the room?

Mr. **Fieldner.** Mr. Thorne is not here.

Mr. **Cole.** Are any of the gentlemen here who assisted those who have testified? I just want to know for the purpose of the record. All right. Thank you. Unless there are some questions, that is all.

Mr. **Fieldner.** Thank you.

## STATEMENT OF HAROLD C. MILLER, SENIOR PETROLEUM ENGINEER, BUREAU OF MINES, DEPARTMENT OF THE INTERIOR

Mr. **Cole.** We will hear you, Mr. Miller. We are glad to see you again.

Mr. **Miller.** I am glad to see you, gentlemen.

Mr. **Cole.** Give us the usual introductory statement of yourself for the record.

Mr. **Miller.** Mr. Chairman, my name is Harold C. Miller. For the past 16 years I have been with the Bureau of Mines stationed in the San Francisco office, and my title is senior petroleum engineer.

I am a graduate of the Michigan College of Mines, now known as the Michigan College of Mining and Technology, and have a bachelor of science and an engineer of mines degree.

In connection with your work, Mr. Chairman, 5 years ago on House Resolution 441, I was senior author of a report, entitled "A Report on Petroleum Development and Production," which Mr. Ben E. Lindsly and I prepared for the use of your committee. Mr. Lindsly now is with the Securities and Exchange Commission and is no longer with the Bureau of Mines.

Mr. **Cole.** In what capacity?

Mr. **Miller.** In what capacity?

Mr. **Cole.** Yes.

Mr. **Miller.** I do not know his title, but his work is petroleum engineering; valuation work, I believe.

I sit here today as the senior author of a report that Mr. G. B. Shea, petroleum engineer, Bureau of Mines, San Francisco, and I have prepared for your committee in connection with House Bill 7372. Mr. Shea is here in the room.

Mr. **Cole.** Mr. Shea, will you stand up so we can see you, please? Thank you.

Mr. **Miller.** Mr. Shea and I beg leave later to submit this report as supplementary testimony to augment my oral statements.

In this report we point out recent progress in petroleum development.

Mr. **Cole.** Mr. Miller, if I may inquire for a little information, am I correct in stating that your report today brings up to date the work in 1934, volume II, pages 1087 to 1306; is that right?

Mr. **Miller.** That is correct.

Mr. **Cole.** All right, sir; you may proceed.

Mr. MILLER. In this report Mr. Shea and I point out briefly some of the improvements in prospecting methods. We point out the number of fields that have been discovered in the last 5 years and tabulate by years the number that have been discovered.

For example, in 1934, there were 70 fields discovered each with an estimated ultimate production of over 1,000,000 barrels of oil and in 1938 the number had increased to 223.

We show in this report that geophysical methods of prospecting now are capable of defining structures 15,000 to 20,000 feet deep, below the surface of the ground, and a still more recently discovered method, called the geochemical method, shows promise of finding oil in areas which geophysical methods have failed to define as probably overlying oil-bearing structures.

We present a short discussion of reserves and point out that during the first half of 1939, according to the best authorities, oil reserves have increased one-half billion barrels, despite an increase of over 9,000,000 barrels in production during the first half of 1939 in comparison with 1938.

We discuss gas reserves and also take up the number of wells that have been drilled during the past 5 years, giving the total number that have been drilled, the number drilled that produced oil and gas, and the number that were "dry."

In 1938, 27,149 wells were drilled, of which 6,043 failed to produce either oil or gas.

We discuss the cost of drilling wells and show that the average cost of drilling a well in the United States is about $21,600. We show also that 26,981 dry holes were drilled during the period since the Miller-Lindsly report was published in 1934, and based on a cost of $21,600, the average cost per year for dry holes is a little over $116,000,000.

The cost of finding oil, that is, the cost of prospecting has averaged about $143,000,000 a year, or 13 cents for every barrel of oil produced.

During the past 5 years 207 holes have been drilled to a depth greater than 10,000 feet, 70 percent of which were drilled in 1938. The deepest depth reached by man is 15,004 feet, in a well in California. This well did not find oil at that depth and was later plugged back to 13,175 feet and is now the deepest producing well in the world, although the deepest producing depth from which a well produced oil was 13,254 to 13,266 feet in a well in Louisiana in 1938.

Mr. MAPES. What was the cost of that well in California?

Mr. MILLER. About $250,000.

Mr. MAPES. How much did it produce?

Mr. MILLER. I cannot give you the figures exactly but I believe the initial production was about 2,500 barrels per day. The well was prorated, and I do not recall what the allowable was at the time the well came in; but now the allowable is less than 200 barrels a day.

Mr. MAPES. Is it in a productive field?

Mr. MILLER. It opened a field; discovered a new area in the San Joaquin Valley.

Mr. MAPES. Are other wells being put down in the field?

Mr. MILLER. There are; yes, sir.

Mr. MAPES. Approximately the same depth?

Mr. MILLER. Yes; to the same sand, at about 13,200 feet.

Mr. Mapes. What is the cost of production in that field, do you think?

Mr. Miller. I cannot give you that, Mr. Mapes; but it is relatively small, because the well flows naturally, and lifting costs are very low when a well flows naturally.

Mr. Mapes. It would take a good many barrels to pay for the original investment?

Mr. Miller. It certainly would.

Mr. Mapes. So that the cost, including the original investment, is bound to be substantial, is it not?

Mr. Miller. Yes; it would be. But the companies have never published that information, and I have no way of determining it.

I might say in connection with what you just asked, that in California, on July 1, 1939, 52 wells were producing from a depth below 10,000 feet even though their allowables are below 200 barrels a day, and they are still drilling more wells to that depth.

Mr. Mapes. How are those wells that cost $250,000 drilled?

Mr. Miller. How are they drilled?

Mr. Mapes. How are they financed?

Mr. Miller. These are all big-company operations. The deepest well was drilled by the Continental Oil Co.

Mr. Mapes. They are oil wells of the major companies?

Mr. Miller. I think all of them are, or could be so classified.

Mr. Mapes. The small independent producer who goes out and sells stock is not in that field?

Mr. Miller. No; I do not think so.

The number of producing wells in the United States in 1938 was 371,875, a gradual increase from 333,070 in 1934. Each year we have more wells producing oil.

Texas has 23 percent of all wells; Pennsylvania 22 percent; Oklahoma 14.7 percent; Ohio 7.4; and each of the rest of the States has less than 7 percent.

In 1937 all production records were broken when 1,279,160,000 barrels of oil were produced, and preliminary figures for 1938 show that there was only a slight decline, but not a very material one in the quantity of oil produced during that year.

The value of the oil produced in 1937 at the well was $1,513,340,000, averaging $1.18 per barrel of oil produced and if we add the value of the natural gasoline and natural gas produced at the wells, the combined value is $1,733,922,000, which is more than 60 percent above the combined value of anthracite and bituminous coal mined during that year, and more than one-third the total value of all minerals.

We find that the natural gas produced and marketed in 1937 reached an all-time high when 2,407,620 million cubic feet of gas, valued at $123,457,000 at the well and $527,529,000 at the point of consumption were produced and marketed.

There are slightly more than 9,000,000 consumers—domestic, commercial, and industrial—of natural gas.

The natural gas used is produced in 24 States, 5 of which—California, Louisiana, Oklahoma, Texas, and West Virginia—produce 80 percent. The gas is used in consuming centers in 35 States, some of which are several thousand miles from the source, and it requires approximately 85,000 miles of trunk lines to transport our natural gas from its source to consuming centers.

Mr. Mapes. Mr. Miller, what is the estimated supply of natural gas; the estimated life of the supply?

Mr. Miller. In our report, we show that the gas reserves of the United States, based on estimates by various authorities, vary from 40,000 billion to 100,000 billion cubic feet, or 30 times the 1938 rate of utilization.

Mr. Mapes. That is larger than I supposed it was. Is that a recent estimate or not?

Mr. Miller. Yes. I can tell you how recent. It was made in 1935.

Mr. Mapes. That means that the known reserves of gas is estimated to last longer than the known reserves of oil.

Mr. Miller. That is correct.

Mr. Mapes. In your judgment, or would you be willing to hazard a guess as to whether in the future more gas fields will be discovered than oil fields?

Mr. Miller. I would say that more oil fields will be discovered than dry gas fields; but it should be kept in mind that most of our gas comes from fields in which oil is produced with the gas.

Mr. Mapes. That is not true of all of them?

Mr. Miller. No; it is not true of all of them, but about 60 percent of our utilized natural gas is produced with oil.

Mr. Mapes. So you think that in the long run oil may possibly outlast gas?

Mr. Miller. If we did not find another oil field, we will still be producing oil, I would say, 50 years from now, but not at the present rate of production.

It is now possible with present machinery to drill wells to depths of nearly 3 miles. Our drilling speeds have increased, and a 10,000-foot well has been drilled in 19 days. We can now drill deeper and faster than formerly and also drill straighter holes. We can drill holes off vertical without having to erect the derrick above the region of the sand that we desire to drain. We can locate the well hundreds of feet away and drill our wells to sands underneath ocean shores or, as has been done in California, underneath cemeteries that could not be drilled by locating derricks inside the cemetery boundaries.

In Ohio, experiments now are being made in sinking a shaft to oil sands, which are of shallow depths in that part of the country, and drilling horizontal holes from the shaft. The shaft is 36 feet in diameter, and it is planned to drill 21 horizontal holes radially from the shaft to drain the sands that have been depleted by ordinary methods of production.

In Texas and certain other parts of the country, because of the low allowables that wells are permitted to produce, many operators are drilling what are called slim holes. The operators start with an 8⅝-inch casing at the surface and finish the wells with 4½-inch casing. The wells can be drilled at about half the expense of the normal well, and inasmuch as they will produce their present daily allowables, and probably the daily allowables that they will be permitted to produce for many years, it is much to the advantage of the operators to drill these slim or small-diameter holes, and in the end make more money than they would if they had drilled conventional-sized holes.

Mr. Mapes. Is that an indication that the industry has reconciled itself to this limited production?

Mr. MILLER. I think many operators have; especially in the Texas Panhandle field, the industry seems to believe that production rates will be limited for many years.

Within recent years methods have been perfected to drill wells in swamps and bayous and in the open waters of the Texas-Louisiana Gulf coast. In swamps derricks are build on wooden mats, and in open water drilling barges are used on which the derrick is erected. After the well is drilled, the barge with the derrick is towed to another site for the drilling of another well.

Progress has been made in drilling heaving shales which have given drillers much trouble. When these shales come in contact with the water in the drilling fluid, they heave and cave into the holes, and it has been impossible to drill through them. We expect in the next few years to be able to combat these heaving shales successfully and reach the oil believed to exist underneath many heaving-shale strata in Texas-Louisiana Gulf coast areas.

Methods have been perfected to take core specimens of oil-bearing sands, so we know more today than we did 5 years ago about the characteristics of the formations in which we find oil and gas.

In our report we discuss the cost of drilling and show that the cost in the United States varies from $3 a foot in areas where the depths of wells are 2,000 feet or less to $20 or more for wells in fields where the productive sands are at great depths.

The cost of drilling wells varies from $2,000 to $250,000, and, as I said before, averages about $21,600. Of course, the cost varies with the depth of the hole, the diameter of the hole, and the character of the formations penetrated, and in the report we give a table showing costs in California that indicate it costs about $21,000 to drill a 1,700-foot hole and $250,000 to drill a 15,000-foot hole.

The trend in well spacing definitely is toward spacing wells farther apart than formerly. Although the Bureau of Mines has made studies indicating that some increase in ultimate recovery of oil is obtained when wells are spaced closely, the increase of recovery due to close spacing is not as great as many of the proponents of close spacing seem to believe.

Mr. MAPES. Will you kindly read that sentence again?

Mr. MILLER. Although studies made by the Bureau of Mines indicate that some increase in ultimate recovery of oil is obtained when wells are spaced closely, the increase in recovery due to close spacing is not as great as many of the proponents of close spacing seem to believe.

Mr. MAPES. In that statement you do not pass upon the question of the ultimate recovery, do you?

Mr. MILLER. No; not in that statement, other than to say that the increase in ultimate recovery due to closer spacing is not as much as proponents of close spacing seem to believe.

Many wells that are drilled in closely spaced fields seem to have been drilled unnecessarily, in that they will fail to increase the ultimate recovery of oil from the pool by an amount sufficient to return the cost of investment, plus the cost of operation and royalties, and a reasonable profit. That, generally is the accepted definition of an unnecessary well.

We point out in the report that probably between 4,000 and 5,000 unnecessary wells are drilled each year in the United States at a drilling cost of $80,000,000 to $100,000,000—about 10 cents per barrel of oil produced.

Mr. MAPES. Suppose you had all power, Mr. Miller, could you to your own satisfaction determine what was necessary or how many wells would be best to be put down in a given field?

Mr. MILLER. I believe I could make a good estimate, based on engineering facts that have been accumulated; yes, sir.

Mr. MAPES. How near do you think the owners in the aggregate of the fields have reached that ideal standard?

Mr. MILLER. I did not get the first part of your question.

Mr. MAPES. How near?

Mr. MILLER. I can cite a large number of fields that are closely spaced, but the trend in new fields today is definitely toward wider spacing of wells than formerly practiced, although we still have town-lot drilling occasionally; but where the opportunity is present to space wells widely, the oil companies are definitely going toward wider spacing.

Mr. MAPES. Do you think the industry itself is working that problem out as rapidly and as well as it is reasonable to expect that it can be worked out?

Mr. MILLER. They are trying to work it out, but there still is room for improvement.

Mr. MAPES. Do you think that the Government could do much to improve that situation over and above what the industry itself is doing?

Mr. MILLER. Perhaps one way the Government could help—and I am not so sure whether that is a way—would be for the Government to make it easier for companies to combine individual operations on small tracts into larger units. In other words, overcome the so-called rule of capture.

Mr. MAPES. In my district, to take a small example, I think that they put a well down on every 10 acres.

Mr. MILLER. Yes, sir.

Mr. MAPES. I know one individual who has a few lots platted outside of the city limits, who has joined in a lease with a producing company to get his percentage of what oil is produced in a 10-acre field. Is that done pretty generally over the country now?

Mr. MILLER. There continues to be too much town-lot drilling, but I do not believe as much as formerly, because most oil companies definitely are trying to get away from close spacing and wherever possible try to pool the small tracts into larger tracts so that fewer wells will be necessary to drain the recoverable oil from the sands.

Mr. MAPES. Perhaps I did not make myself clear. The owners of the different parcels in the 10-acre area have all joined in one lease to one producer, and only one well is drilled.

Mr. MILLER. That is becoming the accepted practice, and the tendency in many areas is to consolidate small tracts.

Mr. MAPES. That is the tendency?

Mr. MILLER. That is the tendency; yes, sir.

In our report we quote from a report prepared in 1936 by the subcommittee of nine of the committee on balance of supply with demand of the Independent Petroleum Association of America to show that in the East Texas field the number of unnecessary wells conservatively is 12,500. At an average drilling cost of $13,000 these wells cost approximately $162,000,000, and in our report we bring those figures up to date, pointing out that approximately 4,000 additional wells have been drilled in the East Texas field since 1936 and that based on today's number of unnecessary wells, the cost of drilling unnecessary wells in the East Texas field perhaps has been more nearly $200,000,000.

The Independent Petroleum Association committee also refers to the Oklahoma City field in its report and states that 360 of the 677 wells actually drilled in that field were unnecessary and that the total cost of drilling those wells was $37,700,000.

We present in our report a table giving the estimated ultimate recoveries, per acre-foot of sand for a number of fields in the United States in which the wells were spaced differently. Although this table shows that estimated oil recoveries per acre-foot vary in some measure with the spacing of wells and are highest, on the average, in fields closely spaced, the data are not directly comparable because the producing sands have different characteristics and are not the same. In other words, if the wells in one field are spaced 10 acres to a well, we have no reason to assume that in other fields where the wells also are spaced 10 acres to a well that we will get the same amount of oil per acre-foot out of those fields. The sand thicknesses and their saturation will be different; the pressure will not be the same; the gas in solution and gas-oil ratios and many other factors enter into studies of recovery and well spacing.

Since I testified before this committee in 1934 we have learned that at least in many, and probably in all fields, all the pore spaces in the producing formation that formerly were considered to contain only oil and gas are not filled entirely with oil and gas, but that some water is present. This water is known as connate water in that we believe the water is a remnant of the water that was with the sands originally, before and during the time that oil accumulated in them. That amount of water in some sands amounts to as much as 50 percent. In other words, the significance of this finding is that former computed estimated recoveries, supposedly varying from 20 to 30 or 40 percent, actually may have been greater and, in place of recovering only 20 percent of the oil that was in the sands originally (if there is 50 percent of connate water in the sand), we actually were recovering 40 percent.

Mr. Lindsly and I, in the 1934 report, presented some figures on the percentage of oil recovered, and I now believe that some of those figures were too low, because so-called connate water was not taken into account in those estimates.

We have also learned during the past 5 years that a barrel of oil in the sand is not a barrel of oil on the surface. In other words, the oil shrinks when produced because of gas coming out of solution, the shrinkage is quite a factor; it varies and may be 25 percent or more. In other words, a barrel of oil in the storage tank may have occupied the space of a barrel and a quarter of oil or perhaps as much as two and a fraction barrels in the sand Considering the solubility of gas in oil and the shrinkage that oil undergoes when produced, we find that this factor also affects our previously calculated recovery efficiencies, and that they perhaps should be higher than we thought formerly.

**Mr. Mapes.** What effect does that have on your estimates of reserves?

**Mr. Miller.** It works the other way on our reserves; taking connate water and shrinkage of oil into consideration, our reserve figures would be less than what we assumed formerly. In other words, if an estimated 15 billion barrels of oil reserves were recalculated considering connate water and the solubility of gas in oil, those reserve estimates actually would be somewhat less.

**Mr. Mapes.** In the estimates which are now made of reserves totaling from 17 billion barrels up to 22 billion barrels in some cases, is that shrinkage taken into consideration?

**Mr. Miller.** I cannot say definitely because I do not know whether it is considered in all of those figures making up that grand total, but I do know that many of the oil companies—at least, all of those I have come in contact with—consider connate water and shrinkage of oil in making their estimates of reserves.

Coming back to our report, we discuss the acidizing of wells; also the disposal of oil-field brines, and point out that in the Mid-Continent three barrels of brine are produced for every barrel of oil. We discuss the high cost of disposing of brines and the methods used. Brines cannot merely be disposed of in creeks and rivers, and it is expensive to build plants and disposal systems to take care of the large volumes of water which are produced with oil.

We discuss also the cost of producing oil and point out that the average costs in 1934, as determined by the former Petroleum Administrative Board, was 80.3 cents per barrel; that according to Bureau of Mines' estimates the average cost in 1937 was 85 cents; and that in June 1938 the cost probably was 1 or 2 cents higher.

We also discuss briefly a number of fields in which unit operations have been practiced, pointing out that successful unitization requires virtually 100 percent participation in order to be as effective as we would like to have it.

**Mr. Mapes.** Is that unitization practice generally adopted now or not?

**Mr. Miller.** No; it is not. The number of fields unitized in one form or another is estimated to be about 185 in the entire United States.

**Mr. Mapes.** Has there been much progress in that respect in the last 5 years?

**Mr. Miller.** There has been some progress.

In the last section of the report we discuss waste of natural gas. You will remember that in the 1934 report, prepared by Mr. Lindsly and me, we cited waste occurring in the Texas Panhandle field, which at that time was approximately 1 billion cubic feet a day. Mr. Shea and I show in our report that gas wastage in that area in 1938 amounted to only 13.6 billion cubic feet for the entire year. Gas wasted in 1938 was 2.2 percent of the total gas produced in that area.

For the entire State of Texas, according to figures furnished by the Railroad Commission of Texas, the volume of gas wasted in 1938 was 137.2 billion cubic feet; in other words, 12½ percent of the total gas produced.

In California 10 percent of the gas produced in 1938 was wasted; 5.3 percent in 1937. Some of this waste resulted from the discovery of some new deep oil-producing sands in southern California.

Mr. Shea and I have discussed in our report some of the items in H. R. 7372 regarding different kinds of waste, and Bureau of Mines engineers have prepared a supplementary memorandum which deals with different forms of waste specifically enumerated in the bill. With your permission, Mr. Chairman, I would like to add this statement to the record to augment my remarks.

Mr. Cole. That may be done.

(The matter referred to is as follows:)

## OIL FIELDS TO WHICH H. R. 7372 WOULD APPLY

(Memorandum Prepared by the Petroleum and Natural Gas Division, United States Bureau of Mines)

In the broad sense, the provisions of H. R. 7372 would apply to every oil field in the United States. This condition springs from the fact that methods and procedure appearing to conform with good principles of conservation in some fields may be judged uncalled-for and reckless waste in others. Likewise, a seemingly "wasteful" practice, under another set of conditions, may have its roots implanted in the conservation motive.[1] Therefore, citations of waste and references to "loss of reservoir energy" require consideration of two basic principles: (1) in the extraction of petroleum from the ground the whole, complex system of a natural reservoir is being dealt with; and (2) advanced as scientific knowledge of the behavior of these systems seems to be, the best present methods may prove to be inefficient and "wasteful" after they can be judged on the basis of a better knowledge of a not-distant future period.

It is fundamental, however, that the behavior of oil and gas in porous reservoir rocks and in their flow to surface equipment is in accord with definite physical laws. Accordingly, an appraisal of what appears to be a wasteful condition (as of any given time or period) can be made with far greater accuracy and equity if it is established in simple terms how petroleum reservoirs behave and what constitutes waste in and from them.

Cattell and Fowler[2] have urged remembrance and recognition of the well-known scientific fact that neither matter nor energy can be destroyed and that terms such as "dissipation of energy" in or "depletion of energy" from natural petroleum reservoirs must mean the loss in the *usefulness* of energy to do work in moving fluids rather than disappearance of energy.

Measurements of energy and its capability of doing work (because of the motion or position of portions of matter in a given system with reference to other portions of matter) are based upon thermodynamic laws. They are far more complicated than measurements of fluids, and attempts to think of energy in quantitative units analogous to those of mass or volume lead to confusion of thought and action.

Present knowledge is fairly widespread regarding the general configurations of natural oil and gas traps containing oil in porous beds between two deformed impervious strata, as represented by a simple "textbook" structure. In an ideal structure, the oil zone is covered by a "gas cap," and water—generally salt water in the lower levels—is below and in contact with the oil. From the oil-water contact the water extends upward into the extraneous parts of the reservoir, completely filling the pore spaces to the lowest level where the porous beds crop out at the surface. The fluid-energy relations, even in simple aspect, in such a structure are not as well known.

For all practical purposes, the forces in such a system are in balance until a well is drilled into a porous stratum of the system containing fluid, thereby unbalancing the equilibrium conditions. According to Cattell and Fowler:[3]

"* * * The oil surrounding the well, with lighter hydrocarbons in solution, starts to flow toward the point of lower pressure at the well bore. As the pressure on the oil is reduced some of the lighter hydrocarbons come out of solution, forming gas. This gas, in expanding toward the region of lower pres-

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[1] See introduction to Paper 12, Section IV, Conservation of Petroleum and of Natural Gas, prepared by the Petroleum and Natural Gas Division and Petroleum Economics Division, U. S. Bureau of Mines, Trans., Third World Power Conference 1936, Vol. VI, pp. 763–794.

[2] Cattell, R. A., and Fowler, H. C., Fluid-Energy Relations in Production of Petroleum and Natural Gas, Bureau of Mines Minerals Yearbook, 1934, pp. 707–721.

[3] Work cited, pp. 710 and 711.

sure, tends to push the fluid ahead of it toward the well, but some of the gas may bypass the oil and move into the gas cap, doing little or no useful work.

"When the fluid reaches the well it consists of a mixture of oil (still saturated with lighter hydrocarbons) and gas. If the pressure and other conditions are adequate, the fluid moves up the well, the gaseous part tending to rise faster than the oil and to slip past it. As the fluid mixture reaches higher levels in the well, where the pressures are lower, more of the lighter hydrocarbons come out of solution joining the gas. Moreover, as this mixture rises and the pressure upon it decreases, the gaseous part expands, doing work on the fluid above it. * * *

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"Important transformations of energy involved in the movement of the fluid mixtures from the reservoir to the surface may be listed as follows: (1) A definite amount of mechanical work must be done to lift the fluid through the vertical distance from its position in the formation to the surface; (2) the fluid must be accelerated from zero velocity at its original position in the formation to the velocity at which it leaves the well head; (3) the friction in the formation, in the flow tube, and in wellhead connections must be overcome; and (4) the energy represented by the pressure head (pressure times volume) at which the fluid leaves the well must be supplied. * * *"

Turning now from this briefed outline of the behavior of natural reservoirs to a consideration of what constitutes waste in and from them: It will be recalled that Miller and Lindsly in an earlier report [4] gave extensive definitions of waste and treated the subject in detail, particularly with reference to State laws in effect and conditions existing in 1934. The brief characterization of the condition by Moore,[5] strictly from the engineering viewpoint, is apropos of the preceding discussion of an ideal reservoir system. He said: "Gas wasted is oil wasted": * * * "water wasted is oil wasted"; * * * and "energy waste (is) prejudicial to all."

Regardless of the varying definitions and characterizations of waste, the subject falls into the following general divisions:[6]

1. Physical Waste.
    a. Surface losses (visible).
    b. Underground losses (invisible).
2. Waste of energy (dissipation of the energy needed for propelling oil through the containing rocks to the wells and thence to the surface).
3. Economic Waste.

It was stated originally with reference to the above listing—and should be kept in mind in the present discussion—that the three items are so interrelated and interdependent that each involves and influences the others.

To say that a certain field is or is not being produced without waste before carefully evaluating and weighting all of the involved factors is contrary to engineering tenets. Particularly important are the economic considerations. The whole mechanism of oil and gas production is inextricably linked with the social economy. For example, without the complications growing out of the American system of ownership, the spacing of wells on a structure could be handled as a problem of fluid mechanics, but because of human frailties more frequently the problem resolves itself into the need for evolving new rules of neighborly conduct.

From the discussion of reservoir behavior it will be seen that in an ideal system each barrel of oil should reach the surface by reason of energy naturally contained in it and that all of the energy should have been used completely in doing useful work by the time the barrel of oil reaches the surface or the stock tank into which it flows. In actual practice, such a condition cannot exist, and, although man can exercise some measure of control over the application and expenditure of reservoir energy in doing useful work and is learning more and more about reinjection into the formation of gas that has

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[4] Miller, H. C., and Lindsly, Ben E., A Report on Petroleum Development and Production: Hearings before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, on H. Res. 441, Petroleum Investigation, pt. 2, 1934, pp. 1226–1248.

[5] Moore, T. V., Application of the Principle of Volumetric Withdrawal to the Allocation of Production: American Petroleum Institute Production Bulletin 212, November 1933, pp. 11–14.

[6] Fowler, H. C., Waste of Petroleum and its Products, Geological Survey Circular 11, Review of Petroleum Industry in the United States, April 1934, Compiled by Hale B. Soyster, p. 23.

reached the wellhead at high pressure, it becomes clearly evident that formerly accepted "good" practices constantly must be and are being revised in order that human actions may be brought more nearly into accord with natural laws.

Nevertheless, the formation of pressure "sinks"—parts of the reservoir where the pressures in the producing horizons have dropped to subnormal values because of excessive volumetric withdrawals of fluid through certain wells—continue to suggest the need for uniform pressure gradients between wells and for reservoir-fluid withdrawals at rates that will prevent "fingering" of the oil-water contact in those fields where the chief propulsive force results from the hydrostatic head of water back of the oil.

Engineers recognize the great difficulties that surround the evaluation of "waste" of reservoir energy because its transformations are so complex that its "availability" on a strictly thermodynamic basis is not necessarily an indication of its usefulness for doing needed work.

Still another complicating aspect in the appraisal of physical waste in a field is the distinction that should be made between waste expressed on a percentage basis and on a quantity basis. For example, a million cubic feet of natural gas is a quantity difficult for most persons to visualize except indirectly in terms of metered domestic consumption. Willfully blowing this or any other quantity of gas to the air is wasteful, but, realizing that no industry can conduct its operations without some loss of material, it is believed that such evaluations should recognize the ratio of unutilized to utilized material and whether the percentage loss is excessive or near the irreducible minimum.

Keeping in mind the foregoing résumé of salient points affecting the appraisal of wasteful conditions in an oil field, it is well to list the causes of waste that have been specified in H. R. 7372:

1. Spacing, location, drilling, completion, or production of any well or wells so as to cause waste of reservoir energy.
2. Loss by escape into the air or by wasteful burning of natural gas.
3. Loss by evaporation, exposure, or wasteful burning of crude oil.
4. Existence or creation of fire hazards.
5. Drowning with water of any stratum capable of producing crude oil or natural gas, or both.
6. Escape of crude oil from a productive formation through drainage, seepage, or uncontrolled migration.
7. Premature release of natural gas from solution in crude oil.
8. Operation of any well producing crude oil with an inefficient gas-oil ratio.
9. Inefficient, excessive, or improper use of reservoir energy.
10. Excessive production of natural gas alone or in conjunction with crude oil from a source of supply containing both even though such natural gas is used or transported for use in the generation of light, heat, or power, or for other purposes.
11. Abandonment of any well in such manner as to render any crude oil unrecoverable or reservoir energy unavailable for the recovery of crude oil.

In subsequent sections, these 11 items are grouped for convenience of discussion (and because of the close relation that several of the items have to each other) under 6 main headings, as follows:

A. Spacing of wells (Item 1).
B. Physical waste of gas at the surface (Item 2).
C. Physical waste of oil at the surface and attending fire hazards (Items 3 and 4).
D. Physical underground waste of oil and gas (Items 5 and 6).
E. Waste of reservoir energy and creation of conditions that cause inefficient ultimate recoveries (Items 7, 8, 9, and 10).
F. Abandonment of wells (Item 11).

At least one, and more often several, of these items cut across the history of virtually every oil field that has been discovered and in which development has started. Even if a field has reached its later declining life, the effect of earlier practices that may have been wasteful is reflected in some way in the present operation and remaining life history of the field. As has been pointed out, it is impossible to extract petroleum from the ground without some waste. Therefore, a tabulation of fields in which waste has or is occurring in some degree and to which the provisions of H. R. 7372 are applicable would be either all-inclusive or of doubtful value—if the considerations pertaining to waste heretofore discussed are accepted as basic. For those reasons, the following paragraphs describe conditions in certain oil fields that have been brought to the attention of the Bureau of Mines and concerning which its engineers have some first-hand knowledge acquired in connection with their work on technical problems of the oil industry—all directed toward more efficient extraction of oil and gas and reduced waste.

Usually the work of the bureau's engineers in a field is directed toward the solution of a specific problem or development of technical information that aids in reducing waste. It has not been the bureau's practice to make investigations primarily for the purpose of determining and reporting upon quantities of waste throughout a field. In other words the Bureau of Mines, as a research and not a regulatory agency, has directed its efforts toward correction of wasteful conditions through application of sound engineering rather than toward establishment of guilt of waste.

### A. SPACING OF WELLS

It is now timely to discuss the first item in the foregoing tabulation—close spacing of wells in a common pool. Most engineers agree that the practices of very close well spacing (specifically, in the Spindletop and East Texas fields in Texas; in the Oklahoma City field, Okla.; in some of the newly developed fields in Illinois; in the townlot areas of Huntington Beach, Long Beach, Santa Fe Springs, and Wilmington fields in California—as well as in many other areas of the United States where ownership of oil and gas rights in a common pool divided among many interests caused the drilling of many wells) were not necessary for the economic recovery of the available oil from the pools underlying those areas. From the economic viewpoint (shown in the forward part of this statement to be the controlling factor in many fields), wells that will fail to increase the ultimate recovery of oil from a pool by an amount sufficient to return the cost of the investment plus the cost of operation and royalties and yield a reasonable profit represent waste of capital and on that basis are unnecessary. Nevertheless, according to Ely[7] 4,000 to 5,000 "unnecessary" wells are drilled each year in the United States at a cost of $80,000,000 to $100,000,000 for drilling costs alone not including the cost of bringing the oil to the surface of the ground.

More specifically, the Subcommittee of Nine of the Committee on Balance of Supply with Demand of the Independent Petroleum Association of America, in its study of the economic factors attending the drilling of wells in certain proved fields,[8] found that 12,500 "unnecessary" wells had been drilled in the East Texas field up to 1936. The subcommittee estimated the total cost of drilling the unnecessary wells to be $162,000,000. More than 4,000 wells have been drilled in the East Texas field since the subcommittee presented its report so that the expenditure for unnecessary wells drilled in that field to date likely exceeds $200,000,000.

The subcommittee also studied the Oklahoma City field and in its report cited that field as another in which more than the necessary number of wells were drilled to extract the recoverable oil economically from the underlying reservoir. In that field, the subcommittee determined, 317 of the 677 wells drilled were unnecessary, and if they had not been drilled, the industry would have saved approximately $31,700,000 in drilling costs.

The broad subject of well spacing is discussed in detail in the report by Miller and Shea[9] submitted to your committee. However, it should be stated here that engineering studies made by Bureau of Mines engineers[10] do not substantiate the view held by many operators and some engineers that the drilling of twice as many wells in a field will recover twice as much oil. For certain ranges of well spacing and under certain conditions of production twice as many wells in a pool may recover about 40 percent more oil, but in general and especially over commonly accepted ranges of well spacing the percentage

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[7] Ely, Northcutt, Legal Restraints on Drilling and Production: Reprint of address delivered before Section of Mineral Law of the American Bar Association, Kansas City, Mo., Sept. 28, 1937, p. 47.

[8] Independent Petroleum Association of America release, December 1, 1936.

[9] Miller, H. C., and Shea, G. B. Report on Recent Progress in Petroleum Development and Production: U. S. Congress, House of Representatives, Hearings on H. R. 7372, 76th Cong., 1st Sess., November 1939. (See p. 351, this volume.)

[10] Miller, H. C., and Higgins, R. V., Review of Cutler's Rule of Well Spacing: Rept. of Investigations 3479, Bureau of Mines, November 1939, 23 pp.

of additional recovery due to the drilling of more wells may be considerably less than 40 percent. Even in those fields where close spacing under the conditions of their operation may have yielded higher recoveries of oil per acre than wider spacing, sight should not be lost of the fact that very close spacing and extremely rapid development, with attending large flush production and resulting unstable conditions, may have been less desirable from an economic and conservation viewpoint than a more stable and dependable output with wider spacing and slower rates of production.

### B. Physical Waste of Gas to the Air

This form of waste has been cited in the literature, in public statements, and elsewhere more extensively than any other because the roar of gas blowing to the air or the flare of flambeaus lighting up a darkened sky can be sensed, recorded, and grasped by the individual. The spectacular aspects of this form of waste need not be recited here.

It will be recalled that in 1934, at about the time this committee was considering H. Res. 441, approximately 1 billion cubic feet of gas was being blown to the air daily in the Texas Panhandle.[11] Naturally, the question should be asked—what are the present conditions? This subject has been discussed in detail in the report by Miller and Shea[12] prepared in connection with H. R. 7372 and is best summarized in tabular form. Accordingly, table 19 of the cited report is included, giving production, utilization, and wastage of natural gas in and from the Texas Panhandle field for the last half of 1935 and for each succeeding year through 1938. Comparable figures are available through August 1939. Recalling that percentage figures frequently are a better gage of gas wastage than over-all volumetric quantities, it will be noted that whereas the total wastage of natural gas from the Texas Panhandle field was 30.8 percent of the gas produced during the last half of 1935, there has been a steady reduction until 1938, when only 2.2 percent of the total production was wasted. By August 1939 this waste had declined to slightly less than 2 percent, almost a practical minimum, considering that the gas is produced from over 4,000 oil and gas wells and 1,500 wells producing gas only.

It is likely that Texas House Bill 266 (enacted May 1935) has been a controlling factor in the reduction of this physical waste in the Texas Panhandle field. According to first-hand reports a considerable part of the present waste results from the inability of production departments, gasoline plants, pipe-line companies, and carbon-black plants to keep their various operations in step.

California is the only other State for which statistics on natural-gas production, consumption, and wastage are available for the 5-year period, 1934–38. It is well to recall that California passed its peak of gas wastage back in 1923 when 59.5 percent of the gas produced was lost for all time.[13] The situation in that State for 1934–38 is discussed in detail by Miller and Shea[14] and summarized in the included table 20 of that report.

During the first 4 years of the period the volume of gas blown to the air was close to an irreducible minimum, but in 1938 there was an increase from 5.3 to 10.3 percent. Only a few fields in California produce gas only. Approximately 95 percent of the gas reaches the wellhead in conjunction with oil-producing operations. The discovery and rapid development of a number of new fields and lower sands in old fields in the later part of 1937 and in 1938 was responsible for this increase in the volume of gas wasted.

Rapid development of deep zones in the West Montebello oil field in 1938 resulted in the wastage of excessive volumes of gas which in May 1939 amounted to 20,874,000 cubic feet per day, and 19.109,000 cubic feet per day in June 1939. During that month the Department of Natural Resources, Division of Oil and Gas, obtained orders from the court, based on previously enacted laws governing gas wastage[15] designating 250 barrels of oil as the maximum a well legally could produce per day from the seventh zone in the West Montebello field. As the gas-oil ratios of the wells completed in the seventh zone may be as high as 6,000 and average 3,000 cubic feet per barrel of oil, the orders were

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[11] See Miller, H. C., and Lindsly, Ben E., work cited, p. 1233.
[12] Miller, H. C., and Shea, G. B., work cited.
[13] Miller, H. C., and Lindsly, Ben E., Work cited, page 1244.
[14] Work cited.
[15] Section 8 B, Act of June 10, 1915 (California).

issued on the ground that curtailing oil production was the only practicable way to conserve the large quantity of gas that was being blown to the air. Unfortunately enforcement of the Department's orders has been delayed by litigation, and wastage of gas continues.

Of the total quantity of gas wasted in California in 1938, oil-producing operations in the Wilmington oil field were responsible for wasting 25 percent. During that year 9,611,835,000 cubic feet or 49.6 percent of the gas produced in that field was blown to the air. In the Kettleman Hills oil field during 1938, 6,459,544,000 cubic feet of gas—16.9 percent of the total volume of gas wasted in California during that year—was blown to the air. This volume of gas wasted in 1938 was less than one-half of the volume wasted in 1937 when gas wastage in the Kettleman Hills field amounted to slightly more than 13 billion cubic feet or 68.6 percent of the total unconserved gas in California in 1937.

Large volumes of gas also have been blown to the air in the Rodessa field in Louisiana and Texas. Available figures of gas produced and wasted in the Louisiana part of the field indicate that up to September 1, 1939, that part of the field produced 444,128,549,000 cubic feet of gas of which 225,247,657,000 cubic feet were blown to the air.[16] A break-down of these figures by months and years would show that the startling conditions of gas wastage attending the early development of the field no longer exist.

Minor wastages of gas are reported [17] to have occurred also in 1938 in Mississippi (350 million cubic feet), Montana (85 million cubic feet), and in the Lance Creek field in Wyoming where the volume of gas lost or wasted during 1938 amounted to 75 million cubic feet.

This brief discussion of physical waste of gas at the surface would be incomplete without reference to untoward circumstances that have or may develop at individual wells.

Wildly blowing wells are exclamation marks in the history of the petroleum industry, and the "burned out" and active craters along the Gulf Coast and particularly in the vicinity of Corpus Christi, stand as mute evidence of the tremendous forces of nature that may be released with disastrous effect when a well gets out of man's control.

In an effort to assist in preventing these occurrences, the Bureau of Mines has treated the subject of blow-outs and means of prevention in its publications.[18] According to the bureau's study, the two principal causes of blow-outs while drilling are inadequate weight and improper consistency of the drilling fluid. Even with an understanding of the causes of blow-outs and diligent execution of safe drilling methods, operators must constantly be on the alert—using preventive measures and employing trained personnel. The following are some of the preventive measures listed by the Bureau of Mines:

1. Pressure-tested casing properly cemented.
2. High-pressure fittings.
3. Dependable blow-out preventers.
4. Quick-closing valves for flow line and drill pipe.
5. Large-capacity, high-pressure slush pumps.
6. Adequate power.
7. Ample supply of properly prepared mud fluid in reserve pits.

Often, loss of control of a well can not be attributed to inattention or carelessness on the part of the operator. Despite every precaution he can take, unexpected conditions may be met, causing him not only to lose his well but also to incur ruinous expense in controlling the hazardous outburst.

Few fields in the deep-seated, high-pressure areas of the Gulf coast have been free from this hazard. Only one present example is cited as typical of the conditions described. It is reported that in the La Belle field, Jefferson Co., Tex., fittings installed on the well proved to be incapable of withstanding the high pressures met at a depth of 8,632 feet and through their failure, the well got out of control. Two months later it was producing 937 barrels of oil and 79,000,000 cubic feet of gas—84.300 cubic feet of gas to every barrel of oil produced. Six months after the well "blew in," it was producing at the rate of 720 barrels of

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[16] Rodessa Engineering Committee, Monthly Report, August 1939.

[17] Minerals Yearbook, 1938, Bureau of Mines, p. 1029 and following.

[18] See Carpenter, Charles B., Some Causes of Blowouts During Drilling and Means of Prevention, with Special Reference to the Gulf Coast Region, Bureau of Mines Information Circ. 6938, 1937, 27 pp.

oil and 70,000,000 cubic feet of gas a day, or 97,000 cubic feet of gas per barrel of oil produced. Since then some remedial work has been done, and the flow of gas has been restricted to 60 million cubic feet per day.

This well is producing through the drill stem which could not be withdrawn from the well when the high pressures were met unexpectedly. Pressures in the well were abnormally high, as shown by the wellhead pressure of 5,400 pounds per square inch. The present wastage of gas from the well is unavoidable until additional corrective measures are taken.

The experience at this well suggests that in drilling in the La Belle field, and in all others where such high pressures may be met, no well fittings or equipment should be used that are not capable of withstanding pressures up to 10,000 pounds per square inch.

### C. Physical Waste of Oil at the Surface and Attending Fire Hazards

In 1933 the Bureau of Mines[19] reported that "the actual physical losses of oil at the surface are relatively small compared with the total production of oil." It was pointed out further that the disposal of oil-field wastes—brines, tank bottoms (b. s. and w.), and similar material—was costly to the petroleum industry. The general condition throughout the industry remains the same now as at the time of the earlier statement. Recent estimates of Bureau of Mines engineers place the capital expenditure for disposal plants alone in Kansas, Oklahoma, Texas, Louisiana, and California at 17½ million dollars.

The subject of petroleum wastes has been discussed in detail by Schmidt and Wilhelm,[20] and various "poor housekeeping" practices are compared with "good housekeeping" methods. Their studies show that by keeping machinery, tanks, and other equipment in good repair and by proper operating methods and treating emulsions, so-called petroleum wastes can be reduced materially and that usually those which form or collect can be disposed of without injury or damage to other property.

A fire hazard exists wherever oil and gas are produced and stored. However, considering the inflammable character of these substances, the high pressures under which oil and gas are produced, and the large quantities handled, the percentage of the oil and gas produced that is wasted as a result of unintentional burning is small. There has been no recent major fire loss of crude oil comparable to two almost simultaneous fires of stored crude oil—ignited by lightning—in two widely separated areas in California in 1926. These fires consumed 7,800,000 barrels of crude oil—approximately 1 percent of the oil produced in the United States in that year. Fires in individual, steel storage tanks have occurred from time to time in various parts of the country, but no record of their occurrence is available.

Most of the important storage facilities for crude oil now are protected against ignition by lightning by grounded networks suspended from steel towers above the storage tanks and reservoirs. Crude and refined oils in storage are protected further against fire by equipping the tanks with internal fire arresting devices and providing external means for combatting fires that might occur.

From the best information available it is concluded that through the intelligent, careful, and watchful supervision of oil- and gas-producing operations and the storing of oil and petroleum products, losses of oil and gas by fire have been reduced to near minimum.

In 1934, Schmidt[21] estimated from tests in the Mid-Continent that total evaporation losses from well through refinery had been reduced from 8.3 percent in 1920 to 2.6 percent in 1934, and from well to refinery the reduction was from 6.2 to 2.0 percent during the same period. No detailed tests have been made recently by Bureau of Mines engineers to determine comparable percentage losses accurately, but it is known that crude oil in transit to refineries and terminals is more volatile than formerly. The reasons ascribed for this condition are: (1) Evaporation of the lighter fractions of the crude oil in lease and gathering operations has been reduced greatly, thereby increasing the volatility

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[19] Bureau of Mines Minerals Year Book, 1932–1933, p. 498.

[20] Schmidt, Ludwig, and Wilhelm, C. J., Disposal of Petroleum Wastes on Oil-Producing Properties, with a chapter on Soils and Water Resources of Kansas Oil Areas, by Ogden S. Jones, of the Kansas State Board of Health. Bureau of Mines Rept. of Investigations 3394, 1938, 25 pp.

[21] See Statement of Ludwig Schmidt, United States Bureau of Mines, Petroleum Investigation, hearings on H. Res. 441, 73d Cong. (recess), pt. 3, pp. 1945–1952.

of the shipped oil; (2) larger quantities of crude oil are being produced from deep horizons, and this oil has a much higher volatility than most of the crude oils from shallow depths. High volatility of oil increases its tendency to lose lighter constituents by evaporation. Accordingly, prevention of loss by evaporation becomes more difficult.

### D. PHYSICAL UNDERGROUND WASTE OF OIL AND GAS

Underground waste in the petroleum industry is less apparent and more insidious than surface waste. Frequently underground waste can be in effect for years without knowledge by the operators that the condition exists.

Oil that otherwise might have been produced, often is lost irrevocably when wells are completed improperly. For example, if a well is drilled through an upper, low-pressure sand to a lower sand of higher pressure and the well casing between the two sands is not cemented properly, oil from the lower sand will pass upward between the casing and the walls of the bore hole and escape into the upper sand. Seldom does the operator realize that upper "thief" sands are receiving some oil that would have reached his flow tanks if the well had been completed properly. In a similar manner, water from a water-bearing sand may travel up or down an annular space between the casing and the walls of the hole that is incompletely filled with cement, enter an oil-bearing sand, and prevent recovery of the oil therefrom or contaminate fresh-water supplies—another form of underground waste associated with the production of oil.

Schmidt and Wilhelm[22] have shown by diagrammatic sketches how fluids may move from one formation to another. Also they have given several citations to waste of this type in Kansas, but they state that contamination of fresh-water supplies by brines from lower formations is not confined to any particular field or general area in the State. It is likely that similar conditions exist in all oil-producing States.

Stalcup[23] pointed out in 1934 that the questionable practice of ripping casing or "shooting" it with explosives to let gas into the producing "string" was applied to hundreds of wells in the Panhandle field of Texas. Recent information is that operators in that field have spent large sums of money to correct the conditions brought about by the practices described by Stalcup and that the attending waste has been reduced appreciably.

An example of an entirely different set of conditions resulting in underground waste because of defective or damaged casing is illustrated by conditions found by Bureau of Mines engineers in a gas well in the Buffalo field, Leon Co., Texas. This well—completed in 1934—had a shut-in pressure of 2,295 pounds per square inch in 1937. When connected to a pipe line in 1938 after negligible quantities of gas had been withdrawn from the reservoir, the pressure was found to have declined to 1,445 pounds per square inch. Studies of depth-temperature relationships in the well made by bureau engineers at the request of the operator indicate that there was an appreciable flow of gas (during the period that the well was shut in) from the productive zone through a rupture in the casing into "thief" sands above the gas-bearing formation. It was not possible to determine accurately the volume of gas escaping into upper sands, but data from tests on the well after it was repaired by the operator indicate that the volume of gas that had escaped into the upper sands was less than 3,800,000 cubic feet per day.

### E. WASTE OF RESERVOIR ENERGY AND CREATION OF CONDITIONS THAT CAUSE INEFFICIENT ULTIMATE RECOVERIES

As natural gas accompanies oil to the wellhead in all oil-producing operations, especially during periods of flush production, and because it is now generally appreciated that gas is an important agency in propelling oil through the sands to wells, widespread efforts are made in most oil-producing areas to control gas-oil ratios of production so that the minimum quantities of gas—irreducible, however, below the quantity in solution in the oil under original reservoir pressure and temperature—are produced with the oil.

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[22] Schmidt, Ludwig, and Wilhelm, C. J., Contamination of Domestic Water Supplies by Inadequate Plugging Methods or Faulty Casing. A report prepared under a cooperative agreement between the U. S. Bureau of Mines and the Kansas State Board of Health, August 1935, 15 pp.

[23] Stalcup, H. M., Petroleum Investigation, hearing on H. Res. 441, 73d Cong. (recess), 1934, pt. 4, p. 2230.

Bureau of Mines studies of "bottom-hole" samples of oil taken in 13 different fields in the Rocky Mountain, Mid-Continent, and Louisiana-Texas Gulf Coast (given in detail in table 13 of the previously cited report by Miller and Shea) show that 357 to 2,190 cubic feet of gas are in solution in 1 barrel of the oil at saturation pressure and temperature. This wide range in the solubility of gas in the reservoir oil at saturation temperature and pressure in different types of reservoirs, ranging from low-pressure, unsaturated conditions to high-pressure, condensate or "distillate" type accumulations, suggests the impracticability of establishing a gas-oil ratio that will be applicable, as an indication of efficiency, to all fields or to a well or field at later periods in its producing life when conditions in the reservoir have changed.

A study of oil and gas production statistics published by the American Institute of Mining and Metallurgical Engineers[24] shows that the average gas-oil ratios in 18 fields, each producing 5,000,000 or more barrels of oil in 1938, varied from 217 to slightly over 5,000 cubic feet per barrel. Obviously some individual wells in those fields had lower gas-oil ratios and others higher ratios than those cited.

Although a minimum gas-oil ratio, as stipulated in several State conservation laws and regulations, is a means designed to conserve gas, designation of one ratio as the minimum for all wells in a State or field is not in accordance with known engineering tenets of oil production. Oil wells produce with varying gas-oil ratios, depending upon reservoir conditions and methods of operation; in the life of a well or field, gas-oil ratios increase usually for a time and then decrease, and the position of wells with respect to the structure and other conditions affect materially the ratios at which wells can be operated efficiently.

In the Wilmington field, California, for example, average gas-oil ratios in January 1938 were 400 cubic feet per barrel; in January 1939, 725, and by July 1, 1939, the average volume of gas accompanying a barrel of oil to the wellhead had increased to 815 cubic feet. Similarly, in the West Montebello field, California, the average gas-oil ratios increased gradually; in January 1939 the average gas-oil ratio was 1,800 cubic feet per barrel; and in June 1939, 2,600 cubic feet of gas were produced per barrel of oil. Obviously, an efficient gas-oil ratio in the West Montebello field, where large volumes of gas are dissolved in the reservoir fluid, will be much higher than one in the not greatly distant Wilmington field, where relatively little gas is in solution in the reservoir fluid.

The foregoing discussion illustrates the fallacy of attempting to stipulate one gas-oil ratio as a measure of efficiency of production in all fields of a State.

The recent development of so-called condensate- or "distillate"-type fields in Texas and Louisiana has emphasized the need for maintaining reservoir pressures in this type of field in order to utilize the reservoir energy as efficiently as possible. According to Patten and Ivey,[25] operations in the La Blanca field, Texas, exemplify methods leading to inefficient and excessive use of reservoir energy. In that field the original reservoir pressure was 4,200 pounds per square inch, and there were 18 barrels of condensate in every million cubic feet of gas produced. Production of large quantities of gas from the field to recover the small quantity of "distillate" that accompanied the gas to the wellhead caused the reservoir pressure to decline rapidly. When the reservoir pressure reached 3,800 pounds per square inch only 9 barrels of condensate were produced per million cubic feet of gas. When the reservoir pressure had declined to 2,180 pounds per square inch the quantity of condensate produced was only 2.6 barrels per million cubic feet of gas. In most condensate-type pools drop in pressure causes the condensate produced with the gas to decrease, until finally the quantity of liquefiable fractions in the gas at the wellhead becomes so small that the wells no longer can be operated profitably for liquid hydrocarbons.

In the Old Ocean field, Brazoria Co., Tex., where the oil is in the gaseous phase in the reservoir, one well in particular is producing 14,000 cubic feet of gas per barrel of oil. Studied thought was given to the waste of gas and reservoir energy, and an attempt has been made to return some of the gas to the formation from which it came. However, it is reported that the injection program has been delayed temporarily until the pressure in the reservoir reaches the range that can be handled by custom-built compressors. During the interim, however, liquid hydrocarbons will continue to condense from the gas in the res-

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[24] Trans. Am. Inst. Min. and Met. Engrs., vol. 132, Petroleum Development and Technology, 1939.

[25] Patten, F. V. L., and Ivey, Denny C., Phase Equilibria in High Pressure Condensate Wells: Oil Weekly, December 12, 1938, p. 20.

ervoir as the pressure declines, and large quantities of them will not be subject to recovery later by known producing methods. From the viewpoint of greatest ultimate recovery of oil, gas should be returned to the reservoir. Whether it would be economical to do so, however, while the reservoir pressure is unusually high, is a problem based mainly on a balance between physical and economic considerations.

As discussed in the forward part of this report, the concepts of reservoir behavior are in a formative stage, and much is to be learned regarding all the factors constituting efficient use of the natural forces derived from the energy in the system. It has been shown that underground physical waste of oil and gas is difficult—and sometimes impossible—to determine until after the damage has been done. Evaluations of so-called energy waste are far more complex. Accordingly, the cited examples are indicative only of what engineers and others are trying to find out concerning better control of reservoir behavior. It would be impossible, with the present state of knowledge, to tabulate the fields that are being operated contrary to the best use of the reservoir energy. Such a list likely would include every oil field yet discovered.

## F. Abandonment of Wells

Oil wells usually are abandoned when their production no longer will cover operating costs. The selling price of oil at the time of abandonment, therefore, is a major consideration in determining when a well will be abandoned. Wells in some fields are abandoned when their production cannot be maintained at 8 or 10 barrels of oil per day; others in areas when the selling price of oil is high and well operating costs are low are operated even when their maximum daily production is 1 barrel or less.

No major oil field in the United States has been abandoned in its entirety, although several large fields (for example, Powell, Wortham, and other Texas fault-line fields) perhaps are nearing the last stages of their ultimate economic producing lives. On the other hand, a number of small fields in the Mid-Continent, particularly in Kansas and Oklahoma and in the Rocky Mountain area, have been abandoned completely because of economic reasons. In California also some former fields, notably the Salt Lake within the metropolitan area of the city of Los Angeles, have been abandoned because of the increase in the value of the real property, although oil still could be extracted from the sands.

The only tabulation of fields abandoned for one reason or another that has come to the attention of the Bureau of Mines is one listing 8 abandoned fields (all of which were small) in the East and East Central area of Texas. In this area 51 fields continue to produce oil.[26] The productive lives of the abandoned fields varied from 8 days to 20 years; the field having the smallest ultimate production yielded 750 barrels of oil during its 5-month life; the largest produced 810,495 barrels of oil during its 20-year life.

In most oil fields increasingly greater quantities of water are produced with the oil during the later stages of the producing lives of the wells. Long before the quantity of oil produced per day from many wells is less than that yielding an operating profit, an equal (frequently a many times greater) volume of water must be lifted for every barrel of oil. The cost of pumping water is approximately the same as that of lifting oil. Accordingly,when excessive quantities of water enter a well with only small quantities of oil, many wells cannot be operated at a profit even though commercial quantities of oil per day still flow to them from the surrounding sands. Many wells, also, are abandoned because the casing in them has corroded or become worn, and the cost of remedial measures cannot be justified by the small productive capacities of the wells.

Most States have laws and regulations requiring the plugging of wells upon abandonment, and the procedures by which a well should be plugged to confine all oil, gas, and water to their naturally occurring strata are set forth specifically. Abandonment of wells on the public domain likewise must conform to certain standards that will cause the oil, gas, and water to be confined in the strata in which they occur.

Obviously, as long as a well is capable of producing oil, even though it may not be economical to do so, its abandonment will leave some oil unrecovered in the sands. In a natural water drive field some of the oil left in the sands about an abandoned well eventually may be flushed by water to producing wells higher on

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[26] Carter, D. V., and Hackbusch, Franklin M., Development and Production in East and East Central Texas: Trans., vol. 132, Am. Inst. Min. and Met. Engr., 1939, p. 413.

the structure, but more than likely the up-structure wells also will be abandoned for economic reasons long before all of the recoverable oil in the abandoned parts of the structure will have migrated with water to them.

## SUMMARY

In summarizing this brief discussion dealing with fields to which H. R. 7372 would apply, it is evident that no individual or research group making studies of problems relating to oil and gas production can fail to recognize that there is waste in some or several forms in virtually all fields and that in certain fields corrective measures can and should be applied. Nevertheless, as in every engineering undertaking, the measure of necessity is economic as well as technologic. The need for corrective measures in the petroleum industry should be gaged by the feasibility of applying them rather than by a strictly numerical evaluation of waste in terms of barrels of oil, cubic feet of natural gas, and foot-pounds of energy.

TABLE 19.—*Sweet, sour, casinghead, and total natural-gas production, utilization, and wastage in the Texas Panhandle oil and gas fields*

| Year | Natural-gas production, M cubic feet | | | | | |
|---|---|---|---|---|---|---|
| | Sweet | | | Sour | Casinghead | Total |
| | East field | West field | Total | | | |
| 1935 (last half)[1] | 43. 701, 290 | 103, 125, 555 | 146. 826, 845 | 63, 070, 053 | 68, 465, 650 | 278, 362, 548 |
| 1936 [1] | 43, 383, 450 | 231, 044, 684 | 274, 428, 134 | 170, 649, 091 | 152, 352, 702 | 597, 429, 927 |
| 1937 [2] | 41, 272, 571 | 236, 725, 209 | 277, 997, 780 | 222, 638, 166 | 135, 865, 107 | 636. 501, 053 |
| 1938 [2] | 40, 214, 563 | 230, 292, 936 | 270, 507, 499 | 221, 979, 183 | 114, 434, 288 | 606, 920, 970 |

| Year | Utilization, M cubic feet | | | | Wastage | |
|---|---|---|---|---|---|---|
| | Extraction loss | Plant lease and other use | Manufacture of carbon black | Delivered to pipe lines | M cubic feet | Percentage of gas produced |
| 1935 (last half)[1] | 12, 193, 982 | 35, 723, 662 | 81, 785, 734 | 63, 057, 516 | 85, 601, 654 | 30. 8 |
| 1936 [1] | 23, 021, 964 | 83, 905, 538 | 223, 432, 855 | 202, 291, 255 | 64, 778, 315 | 10. 8 |
| 1937 [2] | 24, 256, 526 | 72, 252, 871 | 288. 409, 978 | 234. 736, 498 | 16, 853, 550 | 2. 6 |
| 1938 [2] | 22, 269, 391 | 66, 227, 873 | 268, 479, 209 | 235, 040, 862 | 13, 636, 010 | 2. 2 |

[1] Compiled from data given in Oil and Gas Division, Railroad Commission of Texas, Annual Report on the Texas Panhandle oil and gas field: Austin, Tex., August 1937.

[2] Data furnished by the Railroad Commission of Texas.

TABLE 20.—*Oil production and natural-gas production, utilization, and wastage in California, 1934–38, inclusive*

| Year | Oil production, barrels [1] | Natural gas [2] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Casinghead, M cubic feet | Dry, M cubic feet | Total, M cubic feet | Utilization, M cubic feet | Wastage | |
| | | | | | | M cubic feet | Percentage of gas produced |
| 1934 | 175, 508, 566 | 283, 142, 012 | 4, 957, 292 | 288, 099, 304 | 269, 524, 394 | 18, 574, 910 | 6. 5 |
| 1935 | 207, 832, 131 | 307, 313, 874 | 11, 801, 258 | 319, 115, 132 | 296, 045, 463 | 23, 069, 699 | 7. 2 |
| 1936 | 214, 733, 315 | 338, 079, 684 | 5, 784, 611 | 343, 864, 295 | 319, 403, 271 | 24, 461, 024 | 7. 1 |
| 1937 | 238, 520, 383 | 343. 142, 734 | 11, 621, 318 | 354, 764, 052 | 335, 800, 628 | 18, 963, 424 | 5. 3 |
| 1938 | 249, 749, 246 | 362, 054, 223 | 13, 781, 266 | 375, 835, 489 | 337, 601, 673 | 38, 233, 816 | 10. 2 |

[1] Figures compiled by G. R. Hopkins, Bureau of Mines.

[2] Figures compiled from data durnished by State of California, Department of Natural Resources, Division of Oil and Gas.

Mr. **Miller**. That about completes my presentation as far as I have it outlined.

Mr. **Cole**. Mr. Miller, referring to H. R. 7372, I assume you have read the bill and are fairly familiar with its provisions?

Mr. **Miller**. Yes, sir; I have read the bill and am familiar with its provisions.

Mr. **Cole**. Are you able to tell us, from reading that bill, H. R. 7372, of any oil fields in the United States today to which the provisions of this bill would apply?

Mr. **Miller**. At least some parts of the bill would apply to all fields. That is, part of the bill would apply to one field and another part would apply to another field. In other words, all of the fields in the United States in one way or another would be affected by this bill.

Mr. **Cole**. Well, let us take something fairly concrete. On page 9 of the bill, for instance, pages 8, 9, and 10:

> In the promulgation of regulations under this section the Commissioner shall consider and make proper provision concerning, among others, the following factors of waste:
>
> (1) The spacing, location, drilling, completion, or production of any well or wells so as to cause waste of reservoir energy.
>
> (2) The loss by escape into the air or by wasteful burning of natural gas.
>
> (3) The loss by evaporation, exposure, or wasteful burning of crude oil.
>
> (4) The existence or creation of fire hazards.
>
> (5) The drowning with water of any stratum capable of producing crude oil or natural gas, or both.
>
> (6) The escape of crude oil from a productive formation through drainage, seepage, or uncontrolled migration.
>
> (7) The premature release of natural gas from solution in crude oil.
>
> (8) The operation of any well producing crude oil with an inefficient gas-oil ratio.
>
> (9) The inefficient, excessive, or improper use of reservoir energy.
>
> (10) The excessive production of natural gas alone or in conjunction with crude oil from a source of supply containing both even though such natural gas is used or transported for use in the generation of light, heat, or power, or for other purposes.
>
> (11) The abandonment of any well in such manner as to render any crude oil unrecoverable or reservoir energy unavailable for the recovery of crude oil.

Mr. **Miller**. Yes, sir.

Mr. **Cole**. The different factors.

Mr. **Miller**. Yes, sir.

Mr. **Cole**. Do you know of any fields where that would apply?

Mr. **Miller**. You refer to No. 1, Mr. Chairman?

Mr. **Cole**. Yes.

Mr. **Miller**. Close spacing would apply, for example, to the East Texas, the Oklahoma City, the Santa Fe Springs, Huntington Beach, Long Beach, Wilmington, and Spindle Top fields. I am familiar with those fields, and I suppose there are other fields, too.

Mr. **Cole**. Aside from what you have told the committee already, will you not take up in just as brief time as you can the different factors set out on page 9 and tell the committee just how waste is caused by the operations covered in these 11 headings here on pages 9 and 10 of the bill.

Mr. **Miller**. There are three kinds of waste in the oil fields. One is physical waste on the surface; another is underground waste, which may be subdivided into unseen physical waste of unrecoverable oil and gas and the so-called "waste" of reservoir energy. Then there is a third type of waste which is very important—economic waste. We not only have material waste but also economic waste, and they are closely related.

I would say that under No. 1, close spacing of wells in many fields would be classified as waste. It would be an economic waste. There is no need to drill a well, if a person cannot recover an additional amount of oil by reason of the drilling of that well, thereby justifying its cost of drilling and operation. Such a well should not have been drilled. If one well will produce as much oil or almost as much oil as two wells, then why drill two wells?

Mr. COLE. They provide, I understand, in some States for the spacing of wells and I understand that the different States which provide for spacing do not agree in every instance with your views.

Mr. MILLER. The weakness with many spacing regulations is that they specify a spacing pattern and then exceptions are granted which in some cases are all right and in others are not. Unfortunately, when one exception is granted, others must follow almost immediately, and soon spacing regulation becomes almost meaningless. I believe they started out in the East Texas field with a spacing of 10 acres to a well and then granted enough exceptions until today the spacing is about 5 acres to the well on the average.

Mr. COLE. Then if you were in charge of the administration of this bill, for instance, regulations such as you issued would not permit exceptions to the extent that the State of Texas does today?

Mr. MILLER. That would be the ideal condition. If you are going to specify a spacing, you would not be able to maintain those specifications unless you stopped granting exceptions.

Mr. COLE. Would there be any particular difference between a finding on the part of the Commissioner under this bill and the State agencies as to the manner in which the wells should be spaced?

Mr. MILLER. Probably the Federal Commissioner would have about the same trouble that the State agencies are having now. Litigation would ensue and one lawsuit would follow another.

Mr. COLE. Of course, I am assuming that the legality of it is already established as to what the Federal Commissioner might do.

Mr. MILLER. We still would have to get away from long-established views of the rule of capture, which has been interpreted to permit a man to drill and produce a well at will on his property. I see no reason why it would not be possible to establish a well-spacing pattern for a field. I do not think that one spacing pattern will do for all of the fields; some fields might be spaced in accordance with one pattern and in other fields another pattern might be best, depending upon conditions.

Mr. COLE. Suppose under this bill the Federal Commissioner in order to curtail waste would determine that spacing of wells in Texas should be as outlined and the State of Texas determined that they could not do so, or would not do so for certain reasons. Do you anticipate situations of that kind developing to any great extent?

Mr. MILLER. Not from an engineering standpoint, but there might be differences on the legal questions.

Mr. COLE. But not from an engineering standpoint. From an engineering standpoint you are pretty well agreed upon methods upon which spacing should be conducted and engineers are agreed as to the other provisions here on page 9, pretty well?

Mr. MILLER. Yes.

Mr. COLE. You do agree as to those?

Mr. MILLER. Yes.

Mr. COLE. So that regarding subsections 1 to 11, pages 9 and 10, of the bill from an engineering standpoint there is little reason to anticipate much difference of opinion between the Federal Government and State governments.

Mr. MILLER. I would say not.

Mr. COLE. If there is a difference of opinion, which would prevail?

Mr. MILLER. It would have to be a personal opinion. So far as my work in the Bureau of Mines is concerned, it has been mainly fact-finding, so that any answer to the question that I would give would be a personal opinion based on my own experience.

Mr. COLE. Certainly.

Mr. MILLER. With that understanding, I cannot see why it would be any easier for a Federal official (Commissioner) to enforce some of these stipulations than it would be for the States. However, more uniform and consistent enforcement of a policy should be possible under a single administrative head. Some of the States are doing a pretty good job right now. Others are not so good, but they are all working toward that end.

Mr. COLE. I do not mean, Mr. Miller, as to how easy it would be. I mean, concretely speaking, if you and others associated with the Federal Government should determine that a definite practice resulted in waste—that is something you tell me that most engineers very frequently are agreed upon—perhaps the State set-up disagreed with you. Which, under this bill, prevails—the practices which the producers are permitted to follow that are laid down by the Federal Government, or those that are laid down by the State governments.

Mr. MILLER. I really don't——

Mr. COLE. Now, if you do not want to answer, very well.

Mr. MILLER. I believe that I would rather not, Mr. Cole.

Mr. COLE. All right, sir.

Mr. MAPES. May I ask a question, Mr. Miller?

Mr. MILLER. Yes, sir.

Mr. MAPES. Take the East Texas field, for example; to what extent are they putting down new wells there now?

Mr. MILLER. I do not have the exact figures, but from the statement that I made previously, since 1936 some 4,000 wells have been drilled, I would say they are drilling about 2,000 new wells each year.

Mr. MAPES. How many are there in the fields altogether?

Mr. MILLER. About 26,000.

Mr. MAPES. Referring to the first paragraph on page 9 of this bill.

Mr. MILLER. Yes.

Mr. MAPES. Suppose the Commissioner, the Petroleum Commissioner, should find that there was wasteful spacing, location, and drilling of existing wells in the east Texas fields. How could he remedy that situation?

Mr. MILLER. I would say it is too late to remedy the situation after the field virtually is completely drilled.

Mr. MAPES. Take these other fields that you have mentioned—one in California, I believe. The situation would be the same, would it not, in these other fields you have mentioned?

Mr. Miller. I would say it is too late there also. The time to start would be before a field is developed.

Mr. Mapes. Then, as far as spacing or location of wells is concerned, the Commissioner would have to operate pretty largely in new fields, would he not?

Mr. Miller. I would say so; yes.

Mr. Mapes. And, as you have indicated in your testimony, each new field is a law unto itself?

Mr. Miller. Yes, sir.

Mr. Mapes. It would take quite a staff of engineers to visit each field and determine what the spacing ought to be in each individual field, would it not?

Mr. Miller. It would, on a strictly engineering basis.

Mr. Mapes. It would have to be dealt with on that basis to be helpful in preserving oil, wouldn't it?

Mr. Miller. Of course, if in one field the spacing was computed to be, say 10 acres to the well, in a nearby field roughly similar as to thickness of sand, porosity, and other characteristics, you could without much extra effort state that the spacing there also should be 10 acres to the well, and you would not be very far wrong. Accordingly, it might not require a detailed study of every field, but as stated previously, no two fields are exactly alike, and each should be studied in one way or another.

Mr. Mapes. Are you a lawyer?

Mr. Miller. No; I am not.

Mr. Mapes. You are an engineer?

Mr. Miller. Yes, sir.

Mr. Mapes. I take it that is the reason you did not care to express an opinion on the question asked by Mr. Cole?

Mr. Miller. Yes, Mr. Mapes; I am not familiar enough with the legal aspects.

Mr. Mapes. It does not seem to me there is any question about the proper answer to his question as to the theory of this bill, whether one agrees with it or not?

Mr. Miller. Perhaps I did not understand the question exactly, even though you repeated it twice.

Mr. Mapes. If this bill is to have any effect at all, the order of the Commissioner has got to be superior to the order of the State authority has it not?

Mr. Miller. If the bill is to be effective; yes.

Mr. Pearson. Mr. Miller, may I ask you one question: Is there any way from a technical standpoint to tell how great an area any particular producing well will drain oil from?

Mr. Miller. That depends partly upon the type of reservoir. If it is a water-drive reservoir, that is if the hydrostatic head of water behind the oil causes the pressure in the reservoir system, we will have a larger so-called drainage radius than in a field where gas alone is the driving force and water does not encroach upon the structure.

The statement has commonly been made that a few wells or a line of wells in the East Texas field would have drained the whole field. The reason that statement is made is that the oil is underlain by water under a high head, and the water acts as a "water drive" and forces the oil to the wells, and if you wait long enough it would drive the oil to the line of wells near the top of the structure.

On the other hand, some of our fields, like the shallow fields in northeastern Oklahoma, I believe definitely had a so-called drainage radius. According to studies made some years ago by Bureau of Mines engineers the maximum acreage that a well in some fields in that area would drain was about 7 acres.

Mr. PEARSON. Seven acres?

Mr. MILLER. Yes. But that was in a shallow field, where there was not much gas with the oil, and the gas was under low pressure and there was no natural water drive.

Mr. PEARSON. Well, what would you think about the advisability, Mr. Miller—it may be a little out of your line of work, but if you don't mind expressing an opinion—the advisability of Federal legislation of this type applying only to such fields as have not yet been developed, rather than to make it apply to those which are already operating, almost in violation of all of the provisions of this law as it is now written? In other words, would it be a practical thing to undertake now to impose Federal supervision over all of the wells in their present condition?

Mr. COLE. Mr. Pearson, may I interrupt you to say that of course we were discussing the spacing of the wells and not every element of waste. I do not understand that the witness is testifying that waste does not exist in some of the existing fields.

Mr. PEARSON. No; I am referring only to the spacing. I was just wondering about the advisability of legislating for the future rather than to undertake to correct the past errors in such things, or existing errors, particularly in the face of the fact that we have State regulatory bodies in all the producing States, with few exceptions.

Mr. COLE. Will you answer Mr. Pearson's question?

Mr. MILLER. Our wasteful practices, even though in some States we have regulatory bodies, will continue as long as some of the fields are being produced, although progressive operators are trying to overcome all wasteful practices, knowing that it is money out of their pockets to let them continue.

To pass a law to regulate only fields that might be discovered in the future might place a handicap on the fields effected by the law, in competition with some of the older fields. Other difficulties also might come up.

Mr. PEARSON. You think it might put them at a disadvantage from a competitive standpoint?

Mr. MILLER. I did not get your question?

Mr. PEARSON. You think that such legislation might put the new fields at a disadvantage from a competitive standpoint?

Mr. MILLER. I would say so if the bill were modified to apply only to fields discovered in the future.

Mr. KELLY. What is the number now operating in the Illinois fields, do you know, Mr. Miller?

Mr. MILLER. Mr. Kelly, I am not familiar with the Illinois fields, so I cannot answer that question.

Mr. KELLY. Well, I was just wondering whether or not there might be an agreement between the companies operating there, so as to space those fields off?

Mr. **Miller.** I think you will find that in many areas throughout the United States oil companies are realizing more and more that optimum spacing is perhaps the most economic and are agreeing to space wells according to an optimum spacing program or what they believe is an optimum spacing.

Mr. **Kelly.** You have no idea how many wells have been drilled there in the last year?

Mr. **Miller.** In Illinois?

Mr. **Kelly.** Yes.

Mr. **Miller.** No; I have not.

Do you want me to continue?

Mr. **Cole.** Yes; proceed, Mr. Miller.

Mr. **Miller.** The next example of waste would be that caused by completion practices, and that would take into account such items as well-head fittings. In other words, starting at the top of the well a wasteful practice would be to use the fittings that later prove to be lacking in strength to withstand the high pressures encountered and burst, permitting waste of oil and gas.

Subsurface completions that may lead to waste would be improper cementing of water strings in wells so that the fluids would not be confined to their respective strata as, for example, water may enter the hole and flow downward or upward between the walls of the hole and the casing into oil sands which are at a lower or higher level, and drown out the oil.

Another improper completion method would be completing wells with long strings of perforated pipe, so that gas which might be in the upper part of the sand will be produced in large volume with oil from the lower part of the sand. If such wells are properly completed, the gas will not be produced at that particular time and can be used later to cause more oil to flow to the well.

Production methods that are wasteful would include such practices as producing oil with extremely high gas-oil ratios, "blowing" wells to the air in order to clean out perforations or to clean out the channels in the sand leading to the wells, and otherwise permitting wells to produce more gas than if efficient practices had been used.

Other wasteful practices in certain wells would be to produce them at such a rapid rate that water is drawn into the wells, either from underlying parts of the structure or from the edges of the field. There are innumerable examples of this type of waste that I can cite.

Mr. **Cole.** Many of the instances of waste you suggest are such that it is rather difficult for me to conceive of a man who owns a well permitting such waste to take place; that is, on the theory that a man does not want to deliberately waste his property. I assume that some of the instances cited pertain to details and specifications, stock forms of specifications would cover all of them?

Mr. **Miller.** Progressive operators that are in the business of producing oil to make money and to stay in the business, avoid those bad practices wherever they can. The operator, however, who is working on a "shoestring" is forced to get by with as small an expenditure of money as he can, and such wasteful practices likely will occur in his wells.

Sometimes an operator thinks he profits by such wasteful practices, for instance, ripping the casing in some of the wells in the

Texas Panhandle fields. There certain operators ripped the casing opposite the oil and gas sands so that gas from the upper part of the sand flowed into the wells and virtually blew the oil out of the wells. By such practice operators obtained high production and thought they were doing fine. Ultimately they got less production, but they were thinking only of the present and not of the future. Thus in many wells this gas wastage was deliberate.

Considering item 2, the loss by escape of gas to the air. A field was cited to me the other day where an operator generally recognized as progressive in his methods, unexpectedly drilled into a high-pressure gas sand, and before he could get the drill pipe out of the hole the well blew out. That well, I understand, is wasting 40 to 60 million cubic feet of gas a day, and so far he has been unable to bring it under control.

Mr. MAPES. In a case of that kind, what would the petroleum commissioner do under this bill?

Mr. MILLER. I don't believe he could do anything now to stop that waste. A well should be equipped in advance to control the pressures, but in this well the pressure was much higher than normally found at the same depth.

Mr. MAPES. In other words, do you think he would work out a solution of that problem quicker or better than the industry whose selfish interests require it to preserve all the gas it can?

Mr. MILLER. I think that if this well could be capped and wastage of gas stopped, it would have been done long ago. I don't believe anybody can do it right now.

Mr. MAPES. By the industry itself?

Mr. MILLER. By the industry itself; yes, sir.

Mr. MAPES. That is true, isn't it, of a good many of those things?

Mr. MILLER. Yes, sir.

Next consider the loss of oil by evaporation. There is some loss of oil by evaporation. Bureau of Mines engineers estimate that the loss by evaporation from field to refinery is about 2 percent. The companies now are storing their oil in vapor-tight tanks, pipe-line systems are made as tight as possible from one end to the other, and every effort is being made to reduce loss of oil by evaporation. In the supplementary memorandum some figures are given on losses of oil by evaporation.

As far as wasteful burning of crude oil is concerned, it is my experience that such waste is a very minor one. There is very little oil burned wastefully in the fields that I have been in.

No. 5, the drowning with water of any stratum capable of producing crude oil or natural gas: That type of waste sometimes occurs in fields as the result of the corrosion of the casing, also because of imperfect cement jobs. Such conditions are considered wasteful by most companies and usually are remedied. They should be prevented wherever possible.

The escape of crude oil from a productive formation through drainage and for other reasons is a form of waste that does occur to some extent in some fields, and usually is remedied as soon as found.

Mr. PEARSON. Mr. Miller, what practices do the companies willfully engage in which might be classified as economic waste? You have listed a great many things over which they do not seem to have control.

Mr. Miller. Yes, sir. For example, this form of waste has been called to my attention: An operator drilled a well on the top of the structure and found, when he reached the sand, that his well produced nothing but gas. He knew if he could get rid of some of the gas—that is, get rid of the gas in the gas cap above the oil—he would cause oil to flow up the structure to his well. Therefore, he blew gas from his well to the air with the [illegible] that in so doing oil would be drawn up the structure. It has in some wells worked out that way.

I cited an example in a writing some years ago of some operators who followed that very practice and wasted millions and millions of cubic feet of gas in so doing.

Mr. Pearson. They reduced the ultimate oil production, too, didn't they, when they did that?

Mr. Miller. As far as the field as a whole was concerned, the ultimate recovery of oil was reduced due to wasteful blowing of gas to the air.

The proper way to have developed that field would have been to drill the wells farther down on the structure so that they would tap the sand in those regions in which oil occurred and allow the gas cap to remain undrilled. In the particular field I have in mind, there was a natural water drive, and the water drive should have been utilized to drive the oil up the structure at the same time the expanding gas in the gas cap drove it down; in other words, squeeze out the oil. That would have been the proper way to produce the oil in that field.

Mr. Pearson. You say that sort of practice would not be engaged in by a large operator?

Mr. Miller. I would say not as a general practice nowadays—or a small operator either if he is aware of the ultimate damage to him.

Mr. Pearson. Do you think of any other willfully wasteful practice?

Mr. Miller. There was that practice of ripping the casing in the Texas Panhandle field that I cited earlier in my remarks. That was reported by Mr. Stalcup in his testimony before this committee 5 years ago. This statement appears in part 4 of the hearings (pp. 2229–2241). However, that practice today has been largely done away with, because it was wasteful, and because attention of the operators in that field has been called to that form of waste which they should not allow to occur. Most of the operators have taken remedial steps at a considerable expense to improve their former wasteful practices.

Mr. Pearson. You think, then, in the general operation of their business that the industry as a whole is doing what it can to conserve the resources?

Mr. Miller. I would say that on the whole the industry is practicing conservation. I don't believe any operator really wants to waste oil or gas if he can possibly avoid it. It is not his intention to waste it, but, of course, costs of remedial or preventive measures have an important influence upon him. Accidents occur, and of course there are some wasteful practices such as I have just cited among some operators. Many companies have engineering staffs that determine wasteful practices and ways of overcoming them, and those companies especially try not to waste oil and gas.

Mr. Pearson. Well, let me ask you this, Mr. Miller: Where we have a consumer demand for oil that is produced, what good will we accomplish by undertaking through legislative process to limit production in accordance with its ratio to our reserves?

Mr. MILLER. That brings up a point, the ratio of production to reserves, that I do not quite understand. It is my belief that in every oil field there is what I term an optimum rate of production which if exceded—in other words, if you draw oil out of that field at a rate faster than optimum, you will reduce the ultimate recovery of oil from that field. If a field, regardless of the size of the reserve, is efficiently operated and the optimum rate of recovery is determined to be, say, 400,000 barrels of oil a day, then if you withdraw 500,000 barrels a day, the ultimate recovery from that field will be reduced.

Mr. PEARSON. Well, does the converse of that proposition hold true, if you stop production or cap or abandon those wells, that you are apt to bring about the same result?

Mr. MILLER. You mean if you start shutting in those well, will you reduce the quantity of oil recoverable from the field?

Mr. PEARSON. Yes.

Mr. MILLER. Now you are getting into economics. To get the ultimate recovery out of the field at the slow rate, it may be that the rate would be too slow to be economically justifiable.

Mr. PEARSON. Profitable?

Mr. MILLER. Profitable; yes.

Mr. PEARSON. What I meant was, would the abandonment or the stopping of production of the well result in the loss of recoverable oil that that well might produce?

Mr. MILLER. That the particular well might produce?

Mr. PEARSON. Yes.

Mr. MILLER. Yes. I know of wells that have been shut down and after a period of 3 or 4 months when they were again opened they produced nothing but water.

Mr. PEARSON. As a result of that?

Mr. MILLER. As a result of shutting them down. In other words, the up-structure wells had drawn the oil-water contact (interface) past the particular well I have in mind.

Mr. PEARSON. Well, now, if that is true, and under the provisions of this act the Commissioner decided that wells were not properly spaced in any particular field, and he went in by the promulgation of an order and directed that every other well, we will say, in a certain area be closed; by virtue of his action he might be bringing about a loss of recoverable oil if those wells were to continue to operate, would he not?

Mr. MILLER. He might as to those wells which were shut down. But there is another factor that must be considered. If you have a strong edgewater drive in the field, the shutting down of a well does not mean that the oil which otherwise would have been produced from the well if it had continued to operate is lost to man, because the water will push that oil up the structure, and it will go to some other well higher on the structure.

Mr. PEARSON. I see. It would be produced by some other well?

Mr. MILLER. Yes; that is it.

Mr. PEARSON. Under the provisions of this act, it is not inconceivable, is it, that a man or group of men who wanted to develop new territory might almost be in position of those who would have to apply for certificates of convenience and necessity before he could drill and operate a well, would he not?

Mr. MILLER. If in the definition of waste you consider economic waste. In other words, when there is more oil than could be used at the present time, it does seem uneconomic to drill more wells.

Mr. PEARSON. Well, if I had a lease on a tract of land that was adjacent to or not far removed from a producing field and I wanted to drill a well on it, I would be compelled under the provisions of this law to have the approval of the Commissioner before I would be permitted to do it, would I not?

Mr. MILLER. That would depend upon a legal interpretation of the act and regulations issued under it.

Mr. PEARSON. I believe that is all, Mr. Chairman.

Mr. MILLER. No. 7, the premature release of natural gas from solution in crude oil. Fields can be cited where gas has been released from solution in crude oil by lowering the pressure at too rapid a rate.

Mr. MAPES. Mr. Miller, I would like to ask you a question suggested by a question of Mr. Pearson. Suppose the administrator found, or the Commissioner found, that the optimum production of oil necessitated limiting production to about one-half of the present consumer demand. Under the terms of this bill, would it be his duty to put into effect rules and regulations which would reduce the production to one-half the consumer demand?

Mr. MILLER. I have not studied the bill from that viewpoint, Mr. Mapes. In other words, I have been so busy trying to assemble the facts and putting them in the report——

Mr. MAPES (interposing). If that is true, how would you like to be the Commissioner?

Mr. MILLER. I don't know.

Mr. COLE. Mr. Mapes and Mr. Pearson were required to leave.

Have you finished answering the questions as to items 1 to 11, yet? That is what you are on, isn't it?

Mr. MILLER. I have gone well down the list, although I have not exactly followed the order in which they appear. I have spoken about many wasteful practices, and in the supplementary memorandum some additional examples have been cited that I have not mentioned in my oral testimony.

Mr. COLE. I gather from your testimony, or a great deal of it, that in laying down a yardstick or formula, or whatever you might call it, as to governing the conduct of fields in the future, assuming that this bill were approved, it would have provisions covering spacing and location and drilling and other items which you have mentioned and which are covered in Nos. 1 to 11, about which there is little disagreement among engineers. So, if that is the case, it would impose little burden upon the industry. Am I correct in that assumption?

Mr. MILLER. On some of the items there might be some disagreement among engineers.

Mr. COLE. Now, which one?

Mr. MILLER. Proper well spacing, for example, is still a highly controversial subject. Also as to well completions, engineers might disagree on the best methods of completing the wells in particular fields.

In other words, petroleum engineering is still an art dealing with many factors that cannot be tied down to accurate engineering formulas such as we have in most civil engineering and some other engineering work. Petroleum engineering is still a relatively new art, and there is still much to be found out about what happens underground which we cannot see. Such problems must be studied by so-called "remote control." The examples I cited, such as the recent finding that connate water exists in oil-producing sands and that oil shrinks when produced, are only two of many new factors that have come up in the last few years that render many of our previous figures and ideas out of date.

As to specifying in any one stipulation that a condition which applies in one field should apply in others—that cannot be done in the oil industry. Every field, and you might say every well, is a problem of its own. To specify a gas-oil ratio as being most efficient in one field and to consider that it therefore should be most efficient in another, is strictly against all good engineering tenets. In fact, in any one well a particular gas-oil ratio would apply only for a short time, because the gas-oil ratio changes with the age of the well. In general, first it goes up and then it goes down as the well gets older; a similar change in gas-oil ratios takes place for fields as a whole.

Mr. Cole. You do not contend, Mr. Miller, I gather from the last statement as well as some others you have made this afternoon, that production of petroleum, oil, and natural gas can be conducted without any waste whatsoever, do you?

Mr. Miller. I would say definitely that it cannot; the oil industry cannot operate without some waste any more than any industry can be operated without causing a certain amount of waste. I cannot name an industry in which there is not some waste of raw material, and in the oil industry oil and gas are the raw materials.

Mr. Cole. Well, is it possible to estimate what percentage of waste might be tolerated in the industry?

Mr. Miller. No more should be tolerated than is necessary, but it would be difficult to state a percentage considering the waste of natural gas. Take, for example, in California where most of the natural gas is produced with oil, operators have been able to reduce the gas wastage under normal conditions of operation in the State as a whole to less than 5 percent but at times it has been much larger.

The figure that I have for the Texas Panhandle where much dry gas is produced shows that in that field the waste of gas is about 2 percent, but there was a time when it was 30 percent. Evaporative losses have been reduced to about 2 percent. Fire losses are very low; I cannot give you the figures in percentage, but they are very low and must be far below 2 percent. As for losses of oil and gas underground, I don't believe that anybody can estimate what they are. I venture to say, however, that losses of oil and gas underground, through migration from one stratum to another, as a whole are small when compared to the total oil production. The greatest loss is in the oil left underground because of waste of reservoir energy as a result of waste or excessive production of gas.

Although figures of waste above ground appear large when you consider them in terms of millions of cubic feet of gas blowing from wells or from fields, nevertheless, on a percentage basis, this waste above ground may be but 1 or 2 percent, but the waste resulting from failure to recover all oil that could be recovered economically from the producing horizons is much larger.

Mr. COLE. Is that all, Mr. Miller? Does that conclude your statement?

Mr. MILLER. That is all, unless there are some more questions.

Mr. COLE. All right, sir. You will file your report, Mr. Miller, which you and Mr. Shea prepared?

Mr. MILLER. Yes, sir.

Mr. COLE. Thank you very much.

(The report is in full as follows:)

## Report on Recent Progress in Petroleum Development and Production

(By H. C. Miller and G. B. Shea)

Submitted to Special Subcommittee on Petroleum Investigations of the Committee on Interstate and Foreign Commerce, House of Representatives, Seventy-sixth Congress (Recess), on H. R. 7372, November 7, 1939

### LETTER OF TRANSMITTAL

SPECIAL SUBCOMMITTEE ON PETROLEUM INVESTIGATIONS OF
THE COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE,
HOUSE OF REPRESENTATIVES,
*Washington, D. C., November 7, 1939.*

SIRS: We have the honor to submit herewith a report which you directed us to make under authority of House Resolution 7372. The report deals mainly with the major progress in development and production practices, and in petroleum technology that has been made during the five years since the parent report by H. C. Miller and Ben E. Lindsly entitled "Report on Petroleum Production and Development," was submitted to you in November 1934.

This report supplements the preliminary statements presented November 7, 1939 before the Special Subcommittee on Petroleum Investigations.

H. C. MILLER,
G. B. SHEA.

### FOREWORD

In June 1934, the chairman of the Committee on Interstate and Foreign Commerce of the House of Representatives (Seventy-third Congress) appointed a Special Subcommittee on Petroleum Investigation with Hon. William P. Cole, Jr., of Maryland, chairman, to conduct the investigation authorized in House Resolution No. 441.

"The Subcommittee recommended that a thorough investigation of the petroleum industry should include not only consideration of the specific inquiries set forth in the * * * resolution but others definitely related thereto. Consequently, a study was made of the technical side of the problem—i. e., how the reserves of petroleum under the ground could be determined; where those resources were, and to what extent the quantity thereof could be accurately measured; the method of bringing this valuable natural resource to the surface; what happened to it thereafter: its movement through refining processes and all methods of transportation, ultimately reaching the great consuming public and making its contribution into practically every activity known to this age."[1]

As technical advisers on development of oil fields and production practices, the Subcommittee selected H. C. Miller and Ben E. Lindsly of the Bureau of Mines, and their report[2]—a part of the record of the Subcommittee—covered

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[1] Petroleum Investigation (U. S. Congress, House of Representatives, Hearings on H. Res. 441, 73d Cong. Recess 1934), Part I, p. 2.

[2] Report on Petroleum Development and Production: Petroleum Investigation (U. S. Congress, House of Representatives, Hearings on H. Res. 441, 73d Cong. Recess 1934), Part II, pp. 1087–1306.

and discussed, in light of the information available in midyear 1934, such major subjects as (1) the quantity of oil recovered and the effect of improved technology has on increased recovery; (2) changes in engineering views from the day when it was thought that oil flowed in underground rivers to the present concept of reservoir energy; (3) history of well spacing and the relationship between well spacing, energy utilization, and prevention of waste; and (4) methods of production and technical changes that have increased production, either through ability to drill deeper or recover a larger proportion of oil.

On July 26, 1939, Congressman Cole of Maryland introduced a bill (H. R. 7372) known as the Petroleum Conservation Act of 1939, in the House of Representatives. This bill "to promote the conservation of petroleum; to provide for cooperation with the States in preventing the waste of petroleum; to create an Office of Petroleum Conservation; to amend the Act of February 22, 1935, as amended, and for other purposes" was referred to the Committee on Interstate and Foreign Commerce which in turn referred the bill to its Special Committee on Petroleum Investigation of which Mr. Cole again consented to become chairman. In his "Extension of Remarks" in the House of Representatives on July 26, 1939, Mr. Cole said:[3] "It is the idea of the President of the United States that the investigation conducted by our committee in 1934, be brought up to date during the interim between the adjournment of the present session of Congress and next January 1."

Consequently, and pursuant to instructions from Hon. Harold L. Ickes, Secretary of the Interior, in his letter to the Director, Bureau of Mines, Washington, D. C., August 16, 1939, the Bureau of Mines was requested to furnish technical assistance to revise and bring to date those parts of the 1934 Report on Petroleum Development and Production relating to petroleum development, production, and waste of petroleum and its products. H. C. Miller, the senior author of the 1934 report, was selected again to assume the senior authorship of the later report with G. B. Shea to assist him in its preparation, inasmuch as Ben E. Lindsly, junior author of the first report, no longer is a member of the Bureau of Mines' staff.

The report that the present authors have prepared follows.

# RECENT PROGRESS IN PETROLEUM DEVELOPMENT AND PRODUCTION

By H. C. Miller[4] and G. B. Shea[5]

## INTRODUCTION

Five years have passed since the Report on Petroleum Production and Development[6] was written. In the interim notable technologic developments have been made in all branches of the oil-producing industry. Established exploration, drilling, and production practices have been improved and perfected, and many new methods have been developed, enabling the industry to continue the business of finding new accumulations of petroleum and of making them and previously discovered sources available to consumers at minimum cost.

As a result of notable advances in the technique of exploration in recent years the importance of the science of prospecting has increased steadily as it became necessary to probe deeper and deeper for oil. Owing to improvements in the science, cumulative experience, and refinements in interpretations and computations geophysical methods of prospecting for oil and gas have been developed to a high degree of efficiency despite greater prospecting depths and odds against discovery. Each succeeding year has witnessed advancements that have removed barriers to prospecting at deeper levels, and as a result of increasingly successful scientific exploration the number of new fields has been augmented markedly in recent years.

Although geophysical prospecting has been one of the most important factors in the recent discovery of deep oil reservoirs in the United States, the promising

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[3] Cong. Rec. 14158.

[4] Senior Petroleum Engineer, Bureau of Mines, San Francisco, Calif.

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[6] Miller, H. C., and Lindsly, Ben E., Report on Petroleum Development and Production: Petroleum Investigation (U. S. Congress, House of Representatives, Hearings on H. Res. 441, 73d Cong. Recess 1934), pt. II, pp. 1087–1306.

results expected through further development of geochemical methods of prospecting for oil and gas are of major importance to the oil-finding branch of the industry. Already, geochemical methods, based upon the theory that gas from deep oil-bearing formations escapes and seeps to the surface of the ground and that traces of hydrocarbons in the surface soil and "soil air" indicate underlying sources of oil and gas, promise to disclose petroleum-bearing structures of low relief that seldom can be found by geophysical methods. Most significant, however, is the condition that geochemistry applied to prospecting methods appears to be the first scientific development whereby indications of oil and gas in place may be found; all others merely show the existence of favorable structures, and drilling must be depended on to determine the presence or absence of petroleum.

As a result of the success accompanying the search for structures favorable for the accumulation of oil and gas at depths unattainable 5 years ago, improvements in drilling equipment and methods have paced the greater depths to which wells must be drilled to reach the deep-seated structural traps in which the country's major supply of oil is found. Wells drilled 10,000 to 13,000 feet attract no more attention now than 7,000- and 8,000-foot wells a few years ago; one borehole already has attained a depth of 15,004 feet, and even that record may be broken in the near future. As a result of the trend toward higher rotating speeds and analysis of rates of bit penetration, wells not only are being drilled deeper but the average time required to drill a well is constantly being reduced. No longer does it take months to drill a well—the time now is measured in weeks; and although it seems that no further progress in reducing drilling time can be made, records fall almost as rapidly as they are established. The mere breaking of records, however, is unimportant; the significant condition is that development of deep oil-bearing structures seems to involve no unsurmountable problems for the oil industry, and that no matter how far oil may have accumulated under the surface of the ground, the American petroleum industry will find ways to make it available to man at a price that he can afford to pay.

Notable advances in efforts to reduce drilling costs in many oil-producing areas have led to the extensive use of "slim-hole" drilling of exploratory holes for testing deep structures and the application of small-diameter holes in some fields to development operations. Directional (slantwise) drilling has taken a definite place in development operations where oil-bearing sands and rocks cannot be tapped by holes drilled vertically downward from the derrick floor, and oil pools underlying marshes, bayous, and open waters are being developed successfully from derrick sites erected on piers, on sunken barges where the water is shallow, and on floating barges where the water is deep. Important facts have been learned regarding methods for drilling heaving shales, and although the heaving-shale problem has not been solved in its entirety, progress that has been made indicates that in the near future oil accumulated in sands underlying shale beds that heave and slough into drill holes when wetted by water from drilling fluids will be considered part of the Nation's store of recoverable oil.

Imposing advances also have been made in the scientific operation of oil pools, and refinements in oil-producing practices have done much to prolong the economic life of oil fields of every type. Scientific operation of flowing wells, at rates that engineers consider most efficient both from the oil-recovery standpoint and that of economics, has demonstrated that wells in many fields can be operated so that they will produce most of their production by natural flow at minimum lifting cost. Greatly increasing attention is being given to the study of natural reservoirs; to the nature of the fluids in the reservoir, their flow characteristics, and the technique by which the efficiency of recovery can be increased; to formation pressures and means of preventing the formation of pressure "sinks" in the producing pools; to gas-oil ratios of production and methods whereby the minimum quantity of gas is produced with a barrel of oil; and to the conservation of reservoir energy and means whereby the flowing life of wells may be increased and more oil ultimately will be recovered from pools than was possible when the energy was not utilized to optimum advantage in oil production. All these factors have contributed in large measure to lower costs and greater recovery efficiency.

In an endeavor to increase the efficiency of production practices, significant advances have been made in gas-lift equipment and technique. Whereas formerly the gas lift was recognized primarily as a means for pumping large volumes of oil (and water) from wells, today the gas lift is used successfully in many fields where the production allowable per well is small because of proration requirements. To permit production of oil from deep wells after they have ceased to flow naturally or by gas lift, sucker-rod pumping has been developed to such a degree that oil can now be pumped from depths of over 8,000 feet. Unusual advances also have been made in well performance and equipment operation through information gained from studies made with scientific devices that determine the productivity of pumping wells, pumping conditions, and mechanical efficiency of surface equipment.

The improvement in many methods and practices in oil-field operations in recent years may be ascribed indirectly to the production restrictions imposed on the industry. Proration of crude production has changed the economic picture, made oil producers more cognizant than formerly of operating costs, and, more important, has been instrumental in demonstrating the beneficial effects in greater ultimate oil recovery from reservoir sands derived from production control and the conservation of reservoir energy.

That more thought than ever before is being given to the fallacy of drilling more wells than are actually necessary for the economic recovery of oil from pools is evidenced by the increasingly greater distances between new wells. Formerly one well to 10 acres was considered exceptionally wide spacing, but today orderly and efficient development in many fields calls for not more than one well to 20 acres, and often only one well is drilled to every 40 acres. There still are some operators, however, who believe in close spacing of wells, whereas others are as firmly convinced that a spacing of one well to 10 acres or less is much too close for optimum results. "Unnecessary" wells cost the industry millions of dollars yearly and materially increase the unit cost of oil produced. Too close spacing of wells not only furthers waste of reservoir energy but eventually lowers the daily allowable per well to such a level that its revenue often becomes insufficient to yield a profit on the investment in land, drilling and producing equipment, and costs of drilling and operation.

The trend toward wider spacing has shown the need for pooling adjacent tracts too small to be developed by wells spaced uniformly over a field in accordance with modern accepted distances between wells. This in turn has emphasized the need for convincing owners of small tracts of land overlying an oil pool that production in accordance with a broad interpretation of the rule of capture no longer is accepted as good practice by the majority of the industry. The impetus given during the past 5 years to wider spacing and prevention of unnecessary drilling shows the trend toward that type of development.

Progress has been made in unit development of oil fields during the past few years, but the number of fields utilized and operated under a single management still is small.

Evidently there still is much to be done in pointing out to the industry, land owners, royalty interests, and all others concerned with the extraction of petroleum from natural reservoirs the many advantages to be derived through unitization of their holdings in a common pool. Surely it should not be necessary to develop another Santa Fe Springs, Long Beach, Wilmington, Oklahoma City, Seminole, or East Texas to acquaint these groups, the courts, and the public with the inconceivable waste of development investment and permanently excessive operating expense for producing oil from an inordinate number of wells on small tracts of land overlying a common reservoir.

In every branch of the oil-producing industry—exploration, development, and production—executives, technologists, and operators have cooperated in developing and applying improvements in equipment and technique and in attaining more efficient recovery of oil to meet the continually increasing demand for oil, with no increase to the consuming public in price of petroleum and its products.

## ACKNOWLEDGMENTS

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### EXPLORATION

As prospecting for new accumulations of petroleum is the continuing business of the oil industry to a degree not paralleled in any other branch of the mineral group, and as the industry desires to maintain an adequate underground reserve of oil, the search for new petroleum deposits in the United States continues along a wide front. During the past 5 years 752 new oil pools have been discovered in the United States. It has been estimated that 489 of these pools will each produce ultimately over 1 million barrels of oil.[7]

The imposing advances made in recent years in the exploration technique are demonstrated by the fact that the number of major oil fields now found by scientific knowledge and effort far exceeds those discovered by random wildcat drilling which in the earlier days of the industry was successful in pointing out promising oil-bearing areas faster than they were required. Although neither the science of geology nor that of geophysics has advanced to a point where the presence of oil in an underground structure can be determined without actually drilling a well[8] the newer scientific techniques of exploration have enhanced greatly the chances for success once drilling is undertaken. F. H. Lahee,[9] chief geologist, Sun Oil Co., reports that a study of exploratory wells drilled in unproved territory in 1937 and 1938 shows that locations based on technical advice were three times as successful as those made without such advice. Nevertheless, despite imposing advances in recent years in the technique of finding probable oil and gas structures, random wildcatting for oil still is an essential adjunct to scientific exploration to maintain a continuity of supply and to discover new fields before current production requires them.

Table 1, compiled by J. Brian Eby, consulting geologist, shows the number of oil fields discovered in the United States, 1934–38. Those of over 1 million barrels ultimate production are classified by method of exploration. According to the table, random drilling during the 5-year period discovered only 14 new fields, each with an estimated ultimate recovery of 1 million or more barrels of oil, whereas the total number of million-barrel fields discovered by all methods was 489. Table 1 shows also that, as a result of progress during the last 5 years in the technology of oil exploration, more major producing fields, with an estimated ultimate production of more than 1 million barrels of oil each, were discovered than in any year previous.

TABLE 1.—*Number of oil fields discovered in the United States, 1934–38, inclusive, classified by method of exploration*[1]

| Year | Fields of over 1 million barrels ultimate production, classified by method of exploration | | | Other fields[2] | Total |
|---|---|---|---|---|---|
| | Geological | Geophysical | Random drilling | | |
| 1934 | 26 | 18 | 1 | 25 | 70 |
| 1935 | 58 | 30 | 4 | 39 | 131 |
| 1936 | 56 | 38 | 3 | 71 | 168 |
| 1937 | 63 | 44 | 4 | 49 | 160 |
| 1938 | 78 | 64 | 2 | 79 | 223 |

[1] Data taken from table compiled by J. Brian Eby and published in Technology, Employment, and Output per Man in Petroleum and Natural-Gas Production, prepared by O. E. Kiessling, H. O. Rogers, and others as one of the studies of the W. P. A. National Research Project, in cooperation with the U. S. Bureau of Mines, rept. No. E–10, July 1939, p. 336.

[2] Comprises fields of less than 1 million barrels ultimate production.

Because of improvements in the technology of search, petroleum now is found by methods not available a few years ago, and many new pools are being discovered annually in areas that former exploratory methods failed to dis-

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[7] See table 1.

[8] Recent developments in the art of geochemical prospecting indicate that this new science eventually may be perfected to the degree where it may be possible under certain conditions to predict the presence of oil in underground sources without resort to drilling.

[9] Lahee, Frederic H., Further Data on Wildcat Drilling in 1937: Bull. Am. Assoc. Petrol. Geol., September 1938, p. 1235; Wildcat Drilling in 1938: Oil and Gas Jour., March 23, 1939, p. 46.

tinguish as oil bearing. Moreover, many areas where studies of surface geology failed to indicate conditions favorable for oil and gas are being "re-worked" by geophysical methods, particularly with torsion balances and seismograprs.[10] These efforts often are successful in revealing the existence of underground structures favorable for the accumulation of petroleum in areas formerly classified as not likely to contain oil-bearing formations. Furthermore, many areas where the presence of oil and gas deposits was considered unlikely after favorable structures were not revealed by studying surface geology or geophysical prospecting and districts where geophysical prospecting cannot be used successfully to determine the stratigraphy of the underlying formations now are being prospected with some degree of success by analyzing the surface soil[11] and the "air" in the surface strata. The analyses are made to determine traces of hydrocarbons on a quantitative basis on the theory that minute quantities of hydrocarbons in the surface soil and in the soil air of the surface strata indicate underlying deposits of petroleum. Soil-air (soil-gas) prospecting originated in the Union of Soviet Socialist Republics and apparently has been used there successfully by V. Sokolov,[12] who proposed the method, and others, in finding deposits of petroleum in areas where other methods failed to define favorable subsurface structures.

For a number of years the success of geophysics was confined largely to the Gulf coast regions where petroleum is associated with salt domes and trapped in steeply inclined formations, but during the past 5 years the sphere of geophysics has increased because of the "bringing in" of large pools in Illinois and in "deep territory" in California as a result of favorable reports based on seismograph surveys. Furthermore, although structures deeper than approximately 9,000 feet below the surface of the ground could not be mapped successfully by geophysical instruments only a few years ago, no difficulty is experienced today in delineating them at depths of 13,000 to 15,000 feet; in some areas underlain by sedimentary formations beds 25,000 feet below the surface of the ground have been mapped with what appears to be reasonable precision. The accuracy of some of the geophysical surveys and their interpretation is attested by the discovery of over 25 structures in the United States that now are producing oil from depths of 10,000 to 13,275 feet.

Owing to the success of geologists, geophysicists, and other scientists in finding underground structures favorable for the accumulation of petroleum the petroleum industry of the United States continues to be able to produce ample quantities of petroleum and its products to supply a rapidly increasing demand at prices which, on the average, have been low compared with their actual value in terms of energy, service, and convenience. How long the industry can continue to supply the increasing demand for petroleum and its products cannot be answered at this time, but it is apparent to every student of the industry that, although the oil resources of the United States are vast, they are not unlimited and that within a time that is short in the life of a nation new reserves may no longer be found at rates now enjoyed. For the present, however, there appears to be neither an immediate danger of a shortage of petroleum nor an imminent danger of exhaustion of the Nation's petroleum reserves.

Reserves of petroleum continue to be adequate for an extended period at the current rates of production mainly because of extensive exploration for new fields and extension, laterally and vertically, of known fields. As a result, for the past 5 years the industry has been able to maintain known reserves of recoverable oil adequate to supply, at current rates of production, the Nation's needs for 13 or more years.

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[10] Torsion balances are used to measure and record gravity anomalies. Seismographs are of two kinds—refraction and reflection. Refraction seismographs employ the principle of determining the velocity of a shock or compression wave in subterranean rock strata. Reflection seismographs, which virtually have replaced refraction seismographs in geophysical prospecting, record the "echoes" of man-made seismic or earth waves directed downward and reflected by denser strata to "receiving" stations on the surface of the ground. From the records obtained at a number of different locations, the depth of the reflecting strata can be determined and their structural features mapped.

[11] Stormont, D. H., Progress in Soil Survey Methods: Oil and Gas Jour., September 14, 1939, p. 52. See also Stormont, D. H., Gulf Coast Field Is Opened on Soil Survey Information: Oil and Gas Jour., July 20, 1939, p. 28.

[12] Many articles on gas surveying have appeared in the Russian technical press, and English translations of many of them are found in Foreign Petroleum Technology, published in Berkeley, Calif. Professor Sokolov also has published a book on gas surveying, which has been translated into English by the editor of Foreign Petroleum Technology.

Any statement of petroleum reserves given in terms of years' supply should be judged with reference to the fact that, although each new pool discovered means one less to be found in the future, some new fields are found each year in areas previously considered highly improbable of overlying commercial deposits of petroleum. Furthermore, even under rapid rates of production far in excess of those now considered efficient, many oil fields now producing and others to be discovered in future could not be depleted of their recoverable oil in less than 20 or more years.

However, one should not overlook the fact that if the oil reserves of the United States are to be maintained henceforth—as good business dictates—and at least a 12 to 13 years' supply at the current rate of production be "in sight" at all times, slightly more than 1¼ billion barrels of new reserves must be discovered annually.

Can this be done and for how long? This question is foremost in the minds of Government and all those individuals and groups making up the vast and complex interest in petroleum, including the gasoline-consuming public, holders of oil-company stock, bondholders, bankers, equipment manufacturers, suppliers of oil-industry materials, and others who have invested money in oil with the hope of deriving a suitable return from their investments over a long period. Essential in times of peace, petroleum and its products are doubly so in times of war; the very existence of a Nation now depends in large measure on an adequate and dependable supply of fuel oil for its sea forces and gasoline for airplanes and mechanized field units. Military authorities agree that petroleum and its products are equally as essential in warfare as munitions, and a shortage of either is a handicap that probably cannot be overcome successfully by defender or invader.

Obviously, the oil industry cannot go on forever finding new oil pools; the number of pools in the United States is definitely limited; the field of exploration narrows each year, and each newly found pool leaves one less pool for later discovery. Oil pools occur only in porous, sedimentary formations such as sand, sandstones shales, and limestones and then ordinarily in structural folds or domes, remnants of former folds, and old shore lines and other stratigraphic traps. Approximately half of the area of the United States definitely is barren of oil, and in only a small percentage of the remainder is oil likely to be found.

## PETROLEUM RESERVES IN THE UNITED STATES [13]

As of January 1, 1939, proved petroleum reserves of the United States are estimated by the American Petroleum Institute Committee on Petroleum Reserves at 17,348,146,000 barrels, an increase of 1,840,878,000 barrels over the committee estimate of 15,507,268,000 barrels as of January 1, 1938.[14] At the beginning of 1939 four States—Texas, California, Oklahoma, and Louisiana—were reported to have 86 percent of the Nation's estimated total known reserve. Texas exceeds all other States in quantity of oil reserves, which are estimated at 9,447,764,000 barrels (54 percent of the Nation's total). California, with estimated reserves of 3,188,763,000 barrels, had 18 percent of the total recoverable known reserves in the United States as of January 1, 1939; Oklahoma, with 1,162,370,000 barrels of reserves, had 7 percent; and Louisiana, with 1,040,256,000 barrels, had 6 percent.

Illinois (considered from the standpoint of overproduction by many in the industry at the present time as a "fly in the ointment") increased its reserves during 1938 from 40,884,000 to 242,847,000 barrels; this increase of over 200,000,000 barrels in estimated known reserves in 1 year is significant, as Illinois was considered a "has-been" State with respect to petroleum production as late as January 1, 1937. Its revival indicates the possibility of new scientific methods for discovering oil-producing structures previously overlooked. However, despite the large increase in reserves in Illinois, proved reserves in that State on January 1, 1939, are estimated to be but 1.4 percent of the total estimated known reserves of recoverable oil in the United States.

Comparison of the indicated reserves of the United States with the quantity of oil produced in 1938 indicates, as has previously been mentioned, that the

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[13] To augment the following discussion with graphic and tabular data, as of January 1, 1938, the reader is referred to a paper on this subject by the Geological Survey, prepared by H. D. Miser, G. B. Richardson, and C. H. Dane, Petroleum Reserves. See Report of the Energy Resources Committee to the National Resources Committee, Energy Resources and National Policy, January 1939. (House of Representatives Document No. 160, 76th Cong., 1st sess), pp. 286–294.

[14] Oil Weekly, Mar. 6, 1939, p. 13.

country's proved reserves of recoverable oil total about 13 times the quantity of oil produced in 1938. Such a comparison, however, is misleading and gives no clue to the imminence of complete exhaustion of the country's reserves of oil as discussed previously.

The fact that the American oil industry continues to discover more oil than it produces and that the trend of the Nation's crude reserves consistently is upward, reaching an all-time peak at the beginning of 1939, indicates the United States is not yet facing a probable shortage of petroleum and its products.[15] Each year, however, new fields are becoming increasingly difficult to find, each discovery means one less field to be found in the future, and obviously new reserves cannot continue to be found at the present rate to meet the ever-incrasing demand for petroleum and its products. Nevertheless, considering that wells now are being drilled to depths that formerly could not be reached; that new reserves are being discovered rapidly in virgin areas, in formations underlying producing reservoirs, and in lateral extensions of producing fields; and that advances are being made in drilling equipment and technique and in oil-recovery practices, it seems unlikely that oil producers in the United States will fail for some time to come to produce enough petroleum to meet the Nation's consumptive demand.

### NATURAL-GAS RESERVES OF THE UNITED STATES [16]

Garfias[17] estimated the proved reserves of natural gas in the United States at 40,000 billion cubic feet at the end of 1934, equivalent to 20 years' supply on the basis of current consumption. Ley[18] in 1935, estimated that 75,000 billion cubic feet of recoverable gas exist in proved areas of the United States and reported that inasmuch as most of the reserve was in areas productive of oil, part of the gas reserve will be wasted in producing oil. In May 1935 Davis[19] estimated the known natural-gas reserves of the United States as 62,000 billion cubic feet, 11.3 percent of which are in the Appalachian field; 0.2 percent in the North Central States; 75.8 percent in the Mid-Continent and Gulf Coast fields; 3.2 percent in the Rocky Mountain States; and 9.5 percent in California. From a study of the natural-gas resources of California, Hoots and Herold[20] in 1935 estimated the gas reserves of California at 34,000 billion cubic feet, or 28,100 billion cubic feet more than was estimated by Davis. Many important oil fields—Greeley, Ten Section, Wilmington, Rio Bravo, Coles Levee, East Coalinga, Wasco, and others—and a number of gas fields—McDonald Island, Rio Vista, Tracy, and Marysville Buttes—have been discovered in California since 1935, the date of the above estimates, so that there is reason to believe that natural-gas reserves in California exceed even the estimate of Hoots and Herold.

Many oil and gas fields have been discovered also in other States since 1935, so an estimate made today of the natural-gas reserves of the United States probably would indicate a reserve of 90,000 to 100,000 billion cubic feet, or approximately 30 times the quantity of gas produced in 1938.

## SALIENT FACTS AND STATISTICS

### WELLS DRILLED IN THE UNITED STATES, 1934–38, INCLUSIVE

Thirty-two thousand, five hundred and sixty wells, the largest number in the history of the American petroleum industry, were drilled in 1937. Of these, 23,600 produced oil, 2,540 produced gas, and 6,420—almost 20 percent—failed to

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[15] During the first half of 1939 the estimated available reserve supply of oil underground in the United States increased by half a billion barrels, despite an increase of more than 9,000,000 barrels in production over the first half of 1938. See Oil and Gas Journal: July 27, 1939, p. 62. Crude Oil Reserves Increase in First 6 Months.

[16] To augment the following discussion with graphic and tabular data, the reader is referred to a paper on this subject by the Geological Survey, prepared by Ralph W. Richards, Natural Gas Reserves. See Report of the Energy Resources Committee to the National Resources Committee, Energy Resources and National Policy, January 1939. (House of Representatives Document No. 160, 76th Cong., 1st sess.), pp. 294–297.

[17] Garfias, Valentin R., Proven Reserves of Mineral Fuels in the United States: Trans. Am. Inst. Min. and Met. Eng., vol. 114, 1935, p. 243.

[18] Ley, H. A., Geology of Natural Gas: Am. Assoc. Petrol. Geol., June 1935, p. VII, and pp. 1073, 1149.

[19] Davis, R. E., Conservation of Natural Gas in the United States: Gas Age-Record, June 8, 1935, pp. 565–572.

[20] Hoots, H. W., and Herold, S. C., Natural Gas Resources of California—Geology of Natural Gas: Am. Assoc. Petrol. Geol., June 1935, pp. 113–220.

produce oil or gas and were "dry." The number of wells completed in 1938 was 5,411 less than in 1937, and only 2,170 less than in 1926, when the record of wells drilled established a "high" not exceeded until 1937.

Table 2 gives the number of wells drilled during the past 5 years. It also shows how many of these produced oil, how many produced gas, and how many failed to produce either oil or gas. The last column gives the average initial oil production per well per day in barrels.

TABLE 2.—*Wells drilled for oil and gas in the United States, 1934–38, inclusive*[1]

| Year | Number of Wells | | | | Average daily initial production per well, bbl. |
|---|---|---|---|---|---|
| | Oil | Gas | Dry | Total | |
| 1934 | 12, 512 | 1, 373 | 4, 312 | 18, 197 | 358. 0 |
| 1935 | 15, 108 | 1, 401 | 4, 911 | 21, 420 | 375. 3 |
| 1936 | 18, 525 | 2, 068 | 5, 295 | 25, 888 | 318. 7 |
| 1937 | 23, 600 | 2, 540 | 6, 420 | 32, 560 | 342. 9 |
| 1938 | 19, 121 | 1, 985 | 6, 043 | 27, 149 | 356. 2 |
| Total | 88, 866 | 9, 367 | 26, 981 | 125, 214 | ---------- |

[1] Oil and Gas Jour., Jan. 26, 1939, p. 76.

Not all of the wells that failed to produce either oil or gas were wildcat wells; many were drilled to extend the limits of proved fields. The ratio of dry holes to total wells drilled, therefore, does not indicate the chances taken in exploration but does picture one of the hazards accompanying the development of crude-oil reserves.

If, as shown later in this report, the average cost of drilling a well in the United States is $21,600, the 26,981 dry holes drilled during the past 5 years cost the industry approximately $583,000,000—over half a billion dollars or an average of about $116,600,000 per year. Although not all of the dry holes were drilled in strictly wildcat territory and therefore cannot be considered exploratory or prospect holes, the greater percentage of them probably could be so classified. If the cost for geophysical field crews in exploration work over the 5-year period (1934–38), estimated at about $77,000,000[21] (not including staff overhead, research, leasing and drilling developments or seismic damage claims as a result of geophysical operations), and the cost for strictly geological exploration during the same 5 years, estimated at $54,000,000, are added to the cost for unsuccessful exploratory drilling the total 5-year expenditure for seeking new oil fields may be considered to have been approximately $714,000,000—an average of $143,000,000 a year or about 13 cents for every barrel of oil produced during that period.

Since a depth of 10,000 feet first was reached by a drill in May 1931, there has been a rapid increase in the number of wells drilled to that depth and deeper. During the past 5 years 207 holes have been drilled below 10,000 feet; what is more significant, however, is that 145 (70 percent) of them were drilled, as shown in table 3, during the past year. Further evidence of the progress in drilling equipment and technique is the fact that in 7 years more than 5,000 feet was added to the drilling-depth record to establish in 1938 an all-time record for deep drilling when the drilling bit in a well in the Wasco field, California, was advanced to a depth of 15,004 feet—almost 3 miles. At that depth the formations were found to be non-oil-bearing, and the well was plugged back to 13,175 feet, where sands capable of producing oil were opened to production. Although this well is the world's deepest drill hole, the distinction for producing oil from the greatest depth belongs to a well in Terrebonne Parish, La., from which oil was produced for a few weeks from a depth of 13,254 to 13,266 feet.[22] At the end of 1938, however, the well in the Wasco field was the deepest oil producer in the world.

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[21] Kiessling, O. E., Rogers, H. O., and others, Technology, Employment and Output per Man in Petroleum and Natural-Gas Production: WPA National Research Project in cooperation with the U. S. Bureau of Mines, Report No. E–10, July 1939, p. 64.

[22] Bignell, L. G. E., Deep Wells in the United States: Oil and Gas Jour., Sept. 8, 1938, p. 69.

TABLE 3.—*Number of wells drilled below 10,000 feet, 1934–38, inclusive*[1]

| Depth drilled, feet | 1934 | 1935 | 1936 | 1937 | 1938 | Total |
|---|---|---|---|---|---|---|
| 15,000 | | | | | 1 | 1 |
| 14,000 | | | | | 1 | 1 |
| 13,000 | | | | | 8 | 8 |
| 12,000 | | 1 | 1 | 5 | 4 | 11 |
| 11,000 | 3 | 1 | 1 | 5 | 52 | 62 |
| 10,000 | 1 | 5 | 8 | 31 | 79 | 124 |
| Total, all depths | 4 | 7 | 10 | 41 | 145 | 207 |

[1] Oil Weekly, July 31, 1939, p. 59.

The importance of recent deep-drilling operations is emphasized further by the fact that 25 fields having an estimated ultimate oil recovery of 480,750 barrels from sands 10,000 to 13,266 feet below the surface of the ground have been discovered in the United States during the past 2½ years.

Eight of these fields were discovered in 1937, 10 in 1938, and 7 during the first half of 1939; 16 out of the 25 are in the Louisiana Gulf coast region, 7 in California, and 2 in the Texas Gulf coast.[23]

The drilling of many successful wells to depths below 10,000 feet[24] has proved the existence of oil-bearing sands at great depths, and the fact that over 200 wells were successfully completed to such depths with established drilling practices, equipment, and methods demonstrates not only the adaptability of tools and machinery to the needs of deep drilling but that the workers in the industry can meet any problem likely to be encountered in drilling to depths which, a few years ago, were thought beyond the reach of tools.

### PRODUCING WELLS IN THE UNITED STATES, 1934–38, INCLUSIVE

Although the number of wells drilled in the United States increased to an all-time peak in 1937 and then declined substantially in 1938 the number of producing wells increased almost in a straight-line relationship during the past 5 years from 333,070 in 1934, to 369,640—an all-time peak—in 1938.

The number of producing wells in the United States (1934–38) and the average production of oil per well per day in barrels are given in table 4.

TABLE 4.—*Producing oil wells in the United States December 31, 1934–38, inclusive*[1]

| Year | Approximate number | Average production per well per day (barrels) |
|---|---|---|
| 1934 | 333,070 | 7.5 |
| 1935 | 340,990 | 8.1 |
| 1936 | 349,450 | 8.7 |
| 1937 | 363,030 | 9.8 |
| 1938 | 369,640 | 9.1 |

[1] Bureau of Mines figures.

The continuing increase in the number of producing wells is contrary to what the dictates of good business would seem to call for when viewed against the demands for many individuals and companies in the industry for higher allowables for existing wells. When every effort is being made by the majority of oil producers to restrict production to demand the task of allocating to every producing well enough oil production for the wells to pay out in a reasonable length of time becomes increasingly difficult when the number of new wells increases at a faster rate than the demand for oil. That the average production of oil per well per day has increased but slightly since 1934, is significant, inasmuch as the average production per well no longer suggests the

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[23] Oil Weekly, July 31, 1939, p. 62.

[24] On July 1, 1939, in California alone, 52 wells were producing oil from depths below 10,000 feet: Oil Weekly, July 31, 1939, p. 62.

average potential capacities of wells to produce as it did in preproration days, and current output no longer is a guide to the actual producing capacity of flush-production areas. The small incidence in the fluctuations of a curve showing the average production per well for the 5-year period suggests the over-all effectiveness of proration. The slight increase in the average production during the period (keeping in mind that there has been a small increase in total demand for oil) is a natural expectancy.

Despite the fact that the average production of oil per well per day varied only slightly throughout the last 5 years, new wells in many areas are obtaining market connections only with difficulty. Furthermore, in States where oil production is prorated there is a steady shrinkage in allowables as newly completed wells are given their pro-rata share of the existing market. In 1934, for example, the allowable oil production of prorated wells in Texas averaged 40.8 barrels per well per day; but in 1938 the daily allowable was only 23.7 barrels per well, a decrease of 42 percent. The decline in income per well due to reduced allowables in many fields and the increasing difficulty of procuring market outlets for many of the newly completed wells, in many areas has resulted in strong economic pressure to produce in excess of market requirements and sell the oil at less than the quoted price.

Texas leads all States in number of producing wells, with 85,477 at the end of 1938. Pennsylvania, with the second largest number of producing wells in the United States had 82,300 wells at the end of 1938 or only 3,177 fewer than Texas. Average production in Texas during 1938, however, was 15¼ barrels of oil per well per day, whereas in Pennsylvania the average production was slightly more than one-half barrel of oil per well per day. The number of producing wells in the major oil-producing States is given in table 5.

TABLE 5.—*Producing oil wells in the United States at end of 1938* [1]

| State | Producing oil wells | | 1938 oil production, barrels [2] |
|---|---|---|---|
| | Number | Percent of total | |
| Texas | 85, 477 | 23. 0 | 475, 849, 000 |
| Pennsylvania | 82, 300 | 22. 0 | 17, 414, 000 |
| Oklahoma | 54, 632 | 14. 7 | 174, 317, 000 |
| Ohio | 27, 500 | 7. 4 | 3, 287, 000 |
| Kansas | 21, 264 | 5. 7 | 59, 457, 000 |
| New York | 19, 600 | 5. 3 | 5, 036, 000 |
| West Virginia | 18, 100 | 4. 9 | 3. 675, 000 |
| Illinois | 15. 814 | 4. 3 | 23, 812, 000 |
| Kentucky | 14, 200 | 3. 8 | 5, 823, 000 |
| California | 14, 062 | 3. 8 | 249, 906, 000 |
| Others | 18, 926 | 5. 1 | 194, 678, 000 |
| Total United States | 371, 875 | 100. 0 | 1, 213, 254, 000 |

[1] Oil Weekly, Jan. 30, 1939.

[2] Bureau of Mines figures for first 11 months; December estimated by the Oil Weekly, with the aid of weekly reports of the American Petroleum Institute.

Notwithstanding rigid proration in many oil-producing States that tended materially to limit the quantity of oil produced in the Nation, all records of oil produced were broken in 1937, when 1,279,160,000 barrels of oil were brought to the surface of the ground. Preliminary figures indicate that 1938 production was only slightly less than that for 1937.

### CRUDE OIL PRODUCED IN THE UNITED STATES, 1934–38, INCLUSIVE

Table 6 gives the production of crude petroleum in the United States during the past 5 years.

TABLE 6.—*Production of crude petroleum in the United States, 1934–38, inclusive* [1]

| Year | Oil, barrels | Year | Oil, barrels |
|---|---|---|---|
| 1934 | 908, 065, 000 | 1937 | 1, 279, 160, 000 |
| 1935 | 996, 596, 000 | 1938 | [2] 1, 213, 254, 000 |
| 1936 | 1, 099, 687, 000 | | |

[1] Bureau of Mines.

[2] Preliminary.

A recent study,[25] indicates that the oil produced in 1937 (data for other years are not available) had a value at the wells of $1,513,340,000, an average of $1.18 per barrel of oil produced during the year. If the value of natural gas at the wells and natural gasoline at extraction plants is added to the value of the crude oil produced in 1937 the petroleum and natural-gas industry produced in that year products valued at $1,733,922,000, which is more than 60 percent above the combined value of anthracite and bituminous coal and more than a third of the total value of all minerals.

Despite the discovery of new fields, the drilling of approximately 20,000 new wells each year, the increase in number of producing wells, and the increase in imports of oil, little or no actual overproduction of crude oil has occurred because of the relatively strict control exercised over production by most of the leading oil-producing States. Bureau of Mines estimates of demand for crude oil for December 1938, for example, were 3,305,800 barrels per day (see table 7), whereas actual production of oil in the United States during that month, from flush and stripper wells, was 3,275,000 barrels per day—30,800 barrels a day less than the estimated demand. Obviously, imports and withdrawals from stocks had to make up the difference between supply and demand.

TABLE 7.—*Estimates of demand for crude oil for December 1938 and actual production of oil in the United States during that month*

[Oil production, barrels per day]

| Bureau of Mines estimated demand | Actual production [1] | | |
|---|---|---|---|
| | Flush wells | Stripper wells | Total |
| 3,305,800 | 2,240,000 | 1,035,000 | 3,275,000 |

[1] Data from paper by H. C. Weiss, president, Humble Oil & Refining Co., Some Current Problems in Oil Conservation; Oil and Gas Jour., Feb. 23, 1939, p. 46.

### INCREASING DIFFICULTIES OF OBTAINING MARKET CONNECTIONS FOR NEW WELLS

Although stocks of crude petroleum gradually are being reduced the consistently rising volume of new supply continues, drilling in new and in many old fields goes on unabated, and new well completions have a general upward trend. In consequence, there is increasing difficulty in obtaining market connections for many of the new completions. Since the rate of increase in demand for crude oil is not as great as the rate of increase in number of wells completed and their productive capacity, per well allowables in most oil-producing States have continued to drop steadily as the newly completed wells seek their pro-rata share of the existing market. During 1938 the oil industry in established producing areas was forced to bear the burden of increased production from newly discovered areas at the same time that the total national demand for crude oil diminished.

When oil production in Illinois, for example, increased from 4,475,000 barrels in 1936 to 7,499,000 barrels in 1937 and then soared to 23,812,000 barrels in 1938,[26] Oklahoma, Kansas, and other long-established Mid-Continent oil-producing areas were forced to relinquish some of their old markets. Even an area as large as the Mid-Continent cannot lose a market for approximately 20,000,000 barrels of oil per year without affecting the equilibrium of its producing operations. In other words, dumping a new supply of oil in an area already supplied with oil from fields capable of producing more oil than is being withdrawn from the underground reservoirs necessitates an equal reduction in the areas serving the same market outlets. The increase in production due to the drilling and producing of wells in new areas make it necessary for old fields to curtail operations further to prevent a general condition of overproduction; conse-

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[25] Kiessling, O. E., Rogers, H. O., and others, Technology, Employment, and Output per Man in Petroleum and Natural-Gas Production: W. P. A. National Research Project, in cooperation with the U. S. Bureau of Mines, Report No. E–10, July 1939, p. 4.

[26] According to the monthly report of the Illinois State Geological Survey, estimated oil production for August 1939 was 9,269,000 barrels, an all-time-high monthly record.

quently, per well production and revenues decline, and if the trend continues there will be a time when it no longer will be profitable to drill wells or to keep many of the old wells producing. Such a condition seems to be approaching rapidly, and unless some kind of moratorium is declared on bringing in new wells, per well allowables to meet current demand for oil will be so small that oil production no longer will be profitable.

## PRODUCTION OF NATURAL GAS IN THE UNITED STATES, 1934–38, INCLUSIVE

Marketed production of natural gas in the United States reached an all-time high in 1937, when 2,407,620 million cubic feet of gas (see table 8) valued at the wells at $123,457,000 and $527,529,000 at points of consumption was delivered to 9,067,000 domestic, commercial, and industrial users. (See table 9.) In 1938, the marketed volume of natural gas and its value at the wells and at points of consumption declined slightly from that of the previous year, and although the number of consumers of natural gas in 1938 is not available it is believed not to differ materially from that for 1937.

Natural gas is produced in 24 States, 5 of which—California, Louisiana, Oklahoma, Texas, and West Virginia—produce approximately 80 percent of all the gas produced and marketed in the United States. Consuming centers in 35 States receive natural gas from the 24 States in which it is produced, and in order that a constant, dependable supply of natural gas may be available to these consuming areas, some of which are several thousand miles from their sources of supply, 85,000 miles of trunk pipe lines are required.[27]

TABLE 8.—*Marketed production, and consumption of natural gas in the United States, 1934–38, inclusive*[1]

[In millions of cubic feet]

| | 1934 | 1935 | 1936 | 1937 | 1938[2] |
|---|---|---|---|---|---|
| Marketed production: | | | | | |
| California | 268, 122 | 284, 109 | 320, 406 | 329, 769 | 315, 000 |
| Louisiana | 225, 713 | 249, 450 | 290, 151 | 315, 301 | 280, 000 |
| Oklahoma | 254, 457 | 274, 313 | 289, 481 | 296, 260 | 260, 000 |
| Texas | 602, 976 | 642, 366 | 734, 561 | 854, 561 | 845, 000 |
| West Virginia | 109, 161 | 115, 772 | 138, 076 | 149, 084 | 132, 000 |
| Other States | 310, 292 | 350, 585 | 404, 127 | 462, 645 | 431, 000 |
| Total production | 1, 770, 721 | 1, 916, 595 | 2, 167, 802 | 2, 407, 620 | 2, 263, 000 |
| Exports: | | | | | |
| To Canada | 73 | 73 | 84 | 78 | 90 |
| To Mexico | 5, 728 | 6, 727 | 7, 352 | 4, 790 | 2, 000 |
| Imports from Canada | 68 | 106 | 152 | 289 | 375 |
| Consumption: | | | | | |
| Domestic | 288, 236 | 313, 498 | 343, 346 | 371, 844 | 362, 000 |
| Commercial | 91, 261 | 100, 187 | 111, 623 | 117, 390 | 114, 000 |
| Industrial: | | | | | |
| Field | 554, 542 | 580, 414 | 618, 468 | 651, 320 | 620, 000 |
| Carbon-black plants | 229, 933 | 241, 589 | 283, 421 | 341, 085 | 325, 000 |
| Petroleum refineries | 79, 965 | 80, 175 | 93, 183 | 113, 005 | 122, 000 |
| Electric public-utility plants | 127, 896 | 125, 239 | 156, 080 | 170, 567 | 170, 688 |
| Portland-cement plants | 27, 331 | 26, 752 | 36, 923 | 40, 450 | 37, 336 |
| Other industrial | 365, 824 | 442, 047 | 517, 474 | 597, 380 | 510, 261 |
| Total consumption | 1, 764, 988 | 1, 909, 901 | 2, 160, 518 | 2, 403, 041 | 2, 261, 285 |

[1] Table compiled from data in chapter, Natural Gas, by F. S. Lott and G. R. Hopkins, Bureau of Mines Minerals Yearbook 1939, p. 1016.

[2] Subject to revision.

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[27] Richards, Ralph W., Natural Gas Reserves: Chapter 3, Energy Resources and National Policy, a report of the Energy Resources Committee to the National Resources Committee, Washington, D. C., January 1939, p. 294.

TABLE 9.—*Number of consumers and value at the wells and at the point of consumption of the gas produced in the United States, 1934–38, inclusive*[1]

| | 1934 | 1935 | 1936 | 1937 | 1938 |
|---|---|---|---|---|---|
| Number of consumers: | | | | | |
| Domestic........thousands.. | 6, 984 | 7, 391 | 8, 017 | 8, 348 | (2) |
| Commercial........do... | 582 | 613 | 657 | 680 | (2) |
| Industrial[3]........do... | 31 | 36 | 39 | 39 | (2) |
| Value (at wells) of gas produced: | | | | | |
| Total........thousands of dollars | 106, 438 | 110, 402 | 119, 193 | 123, 457 | 110, 887 |
| Average per thousand cubic feet........cents.. | 6. 0 | 5. 8 | 5. 5 | 5. 1 | 4. 9 |
| Value (at point of consumption) of gas consumed: | | | | | |
| Domestic........thousands of dollars.. | 215, 029 | 233, 940 | 251, 617 | 273, 577 | 267, 880 |
| Commercial........do... | 45, 287 | 49, 386 | 53, 693 | 57, 161 | 55, 860 |
| Industrial........do... | 133, 941 | 144, 748 | 170, 129 | 196, 791 | 176, 748 |
| Total value........do... | 394, 257 | 428, 074 | 475, 439 | 527, 529 | 500, 488 |

[1] Table compiled from table in chapter, Natural Gas, by F. S. Lott and G. R. Hopkins, Bureau of Mines Minerals Yearbook 1939, p. 1017.

[2] Figures not yet available.

[3] Exclusive of oil- and gas-field operators.

## DEVELOPMENT

Today the technique of drilling of wells for oil and gas, especially that used in drilling to great depths, is a highly specialized and efficient art. Not only are wells being drilled increasingly deeper, but because of improvements in equipment and advanced drilling practices, it now is possible to reach depths of nearly 3 miles at speeds closely approximating those at which wells were drilled to only 5,000 feet a few years ago. Drilling-speed records continue to be bettered almost as soon as they are made; the latest drilling record (which also may have been excelled by the time this report is published) was established recently when a wildcat well in California was drilled to a depth of 10,000 feet in an elapsed time of 19 days, including the time required to line the well with 1,500 feet of surface casing.[28]

Rotary drilling largely has displaced slower cable-tool methods, although the latter still are preferred in some areas, especially in those regions where drilling depths are shallow enough to permit use of portable drilling rigs and drilling machines and in some limestone fields where cavernous strata prevent a successful use of drilling fluid. Although some changes and improvements have been made in cable-tool equipment and technique during the past 5 years none can compare with the advancements in rotary-drilling machinery and practices. Although in the regular course of events normal improvements in design and construction would have been made to meet the demands for greater efficiency in drilling, most of the improvements in rotary equipment and practices have been brought about in the past half decade in consequence of the need for drilling to increasingly greater depths at constantly accelerated speeds.

### PROGRESS AND TRENDS IN DRILLING EQUIPMENT AND TECHNIQUE

#### DRILLING MACHINERY

As drilling progressed deeper, heavier and larger drilling machinery and more powerful power units were designed and built to handle the heavier loads and increased speed requirements of deep drilling. The largest, heaviest, rotary-drilling outfit in the United States is believed to be one designed to drill to a depth of 17,500 feet, now operating in the Rio Bravo field in California. The equipment at the well includes five 130-horsepower, gas-fired boilers, supplying steam at a pressure of 500 pounds per square inch to a 15- by 14-inch twin engine; a 3-speed drawworks weighing 48,220 pounds with a 40-inch double rotor hydromatic brake; a rotary table with a 20½-inch opening for lowering bits and casing into the borehole, driven at 350 r. p. m. by a 12- by 12-inch twin steam engine installed under the derrick floor; a 300-ton-capacity traveling block; and crown blocks with 48-inch sheaves.

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[28] Mills, Brad, Improved Practices Permit High Speed Deep Drilling; Oil Weekly, July 31, 1939, p. 66.

To accommodate the larger traveling blocks and casing hooks now used—many designed to carry loads up to 500 tons—and to provide floor space on the derrick floor for racking the long strings of drill pipe used in modern drilling, taller, larger-base derricks have been designed. In many fields 136-foot derricks with 26-foot square bases are being replaced by 178-foot derricks with bases 32 feet square. Such derricks accommodate more than 2 miles of drill pipe in stands 120 feet long. Steel substructures and fabricated steel bases for derricks, engines, and drawworks have been generally adopted during the past few years, and many derricks now have extended legs to raise the derrick floor approximately 8 feet above the level of the ground and permit the use of steel substructures and fabricated steel bases for engines and drawworks. Moreover, by elevating the derrick floors, headroom is provided for easy access to well-control equipment, and deep cellars underneath derrick floors are not needed to accommodate the necessary control valves and blow-out preventers.

To meet the need for increased power and higher engine efficiencies oil-field boilers, usually in batteries of four, capable of generating steam at a pressure of 350 pounds per square inch recently have come into general use for heavy-duty operations. Even more remarkable is the fact that at one drilling operation in California a battery of five domeless-type boilers rated at 130 horsepower each is operating at a working steam pressure of 500 pounds per square inch with the steam superheated to 650° F.

The use of superheaters in oil-well drilling is becoming more general throughout many areas where wells are drilled to great depths. Superheaters increase the capacity of boilers about 25 percent and furnish drier steam to the power units on the derrick floor. More and more oil-field boilers are being insulated and boiler feed water preheated to temperatures as high as 200° F. by utilizing the heat in the steam exhausted by the drilling engines and mud-fluid-circulating pumps to affect material savings in the cost of fuel. Many other fuel-conserving and labor-saving pieces of equipment, such as low-pressure draft-controlled burners, feed-water-control devices, low-water alarms, and water-treating units, none of which was used in the oil fields a few years ago, now are being employed in growing numbers to increase the efficiency of boiler plants at drilling wells.

To meet the needs for more power and greater speed in oil-well drilling, larger and improved types of steam engines are used, the largest of which is a specially designed 15- by 14-inch, 1,700-horsepower twin-drawworks engine operated by steam under a pressure of 500 pounds per square inch. The use of individual engines to drive the drawworks and the rotary table instead of one engine for both pieces of equipment is another recent development that has come into fairly general use in deep-drilling operations.

The design of the hoisting equipment (drawworks) at drilling wells differs widely from that of a few years ago. Today, three-shaft, multiple-speed, fully enclosed, heavy-type units capable of handling heavy loads safely are in evidence in many oil fields. Drawworks now are anchored to the derrick sills, whereas formerly they were held in place by headboards or beams. Hydromatic brakes which depend for their braking capacity upon fluid friction instead of dry friction have come to be almost indispensable adjuncts to conventional braking facilities for handling the heavy loads of deep drilling. Improvements in the quality of brake linings and in methods of cooling brake drums also have provided better braking facilities.

Deeper drilling has increased materially the loads that must be handled by the wire drilling lines. For shallow- and medium-depth drilling 1-inch-diameter lines usually were strong enough to handle the comparatively light loads that were raised and lowered in derricks, but where wells are drilled to great depths 1⅛- and 1¼-inch-diameter drilling lines are necessary.

Many improvements also have been made in other machinery used in drilling oil wells. For example, rotary tables with gears running in oil now are built for rotating speeds unthought of a few years ago. Until quite recently, rotary-table speeds averaged about 125 r. p. m., and general practice in the Gulf Coast and Mid-Continent areas still is to rotate the drill at 85 to 150 r. p. m. In California, however, during the past few years the speed of rotation of the drill pipe and bit has increased gradually, and in 1938 several wells were drilled at maximum rotational speeds of about 400 r. p. m. In 1939, while drilling below 7,000 feet, one operator even went so far as to rotate the drill pipe at speeds of

500 to 575 r. p. m.[29] The highest rotating speeds ever reached in rotary drilling were obtained by the recently developed turbo drill that operates by pressure of the mud fluid.[30] On one test, with a 5-inch turbine driving an 8-inch bit, a

Studies of high-speed rotation of the drill stem and bit indicate that speeds as high as 600 r. p. m. with conventional-type rotary equipment may have certain advantages in making it possible to drill holes even more rapidly and economically than is now possible. Many operators, however, do not look with favor upon such high rotating speeds and regard 250 r. p. m. as being about the safe maximum speed for ordinary drilling; others consider 300 to 350 r. p. m. the practical limit with average heavy drilling equipment and steam pressures of 350 pounds per square inch.

Important changes also have been made in rotary drives, particularly adoption of auxiliary engines to drive rotary tables. Individual rotary-table drives assure better control of the movement of the drill pipe and reduce wear on the draw works and draw-works engine. Standby hoists are installed at many drilling wells for raising the drill pipe in an emergency. These standby hoists, however, should not be confused with the lighter power-driven sand reels that are becoming standard equipment at wells being drilled to great depths and are used for bringing wire-line core barrels out of boreholes and running in and bringing out retractable drilling bits.

At the great depths now being reached by the drill, pump pressures as high as 1,200 pounds per square inch are required to circulate the mud fluid used to plaster the walls of boreholes to make them "stand up" and to bring the drill cuttings to the surface of the ground. In emergencies, as when stuck drill pipe is to be freed, mud-fluid-circulating pumps may have to overcome pressures as high as 4,000 pounds per square inch, and for such high-pressure operations two pumps usually are compounded or connected in series. Increasingly greater use is being made of "shale shakers," centrifugal separators, and vibrating screens to remove sand and cuttings from the circulating mud fluid and to liberate entrained gas from the mud stream so the mud fluid will be less abrasive to pumps, drill pipe, and bits and its weight and viscosity will be unimpaired by gas from subsurface formations.

Drill stems to which the drilling bits are attached are being made of better-grade steel than heretofore, and the ends of the drill pipe generally used to make up the drill stems are upset externally instead of internally to provide minimum friction to the downward-moving stream of mud fluid and to give unobstructed passage to wire-line core barrels and retractable bits. Larger tool joints with improved threads are used to give more secure connections between the stands of drill pipe making up the drill stem than former smaller tool joints afforded and to reduce the risk of "twist-offs." Drilling bits also have been improved in design and construction, and the best steel available is used in order that they will remain sharp and "stand up" as long as possible under the high rotating speeds and great weights placed upon them. If it is realized that in deep-drilling operations 4 to 8 hours or more is required to "come out of the hole" with drill pipe, change bits, and "run back in" the need for using bits that will make large footage before becoming too dull to continue "making hole" is appreciated. No wonder that most drilling bits now used in deep-well drilling are faced with hard metals and alloys to extend drilling life.

Many of the major advancements made in drilling equipment during the past few years have been described briefly, and although many other noteworthy improvements might be cited, a review of them would only emphasize further the fact that the oil industry and manufacturers of oilfield equipment constantly are striving to improve drilling equipment, tools, and methods to meet the ever greater demand of deeper, faster, more economical drilling.

### DRILLING-CONTROL INSTRUMENTS

Effective control of rotary-drilling operations is aided by instruments and gages that indicate the weight of the drill stem on the bit, torque in the drill pipe, speed of the rotary table, pressure on the mud pumps, and load on the derrick. These gages often are supplemented by recording instruments that provide a

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[29] Sawdon, Wallace A., Developments in Drilling Technique in California; Petrol. Eng., Midyear 1939, p. 131.

[30] Sawdon, Wallace A., The Turbo Drill—A Development that May Lead to Changes in Present Rotary Drilling Practice: Petrol. Eng., June 1938, p. 35.

speed of 1,200 r. p. m. was attained.

continuous record of the drilling performance. Several types of automatic controls that depend either on the torque in the drill pipe or the weight on the bit have been developed for feeding the bit in the hole as drilling progresses. Although these methods of control are not widely used experience shows that where automatic-feed controls have been used not only were the driller's duties lightened but straighter holes were drilled, and greater footage was made per bit with less wear and strain on the drilling equipment. In drilling deep wells efficient cutting action of the bit and drilling the hole straight depend largely on proper correlation of the speed of rotation of the drill pipe, weight on the bit, and the pressure of the circulating mud fluid. The deeper the well the more important becomes the need for balancing these factors properly. With increased rotating speeds the weight on the bit has been more than correspondingly increased. During rotation at 500 r. p. m. a California operator drilled with about twice as much weight on the bit as with former slow speeds. In tests to determine the actual weight on the bit one operator has applied 5 to 15 tons, depending on the formation.

Greater loads on the bit have made the use of weight indicators increasingly important, and to meet the demands of deep, rapid drilling more accurate and sensitive weight indicators now are being built than were constructed formerly. In modern deep-drilling operations it is now accepted practice to maintain the drill pipe in tension during drilling by using several heavy drill collars in the drill stem to provide the needed weight on the bit. Accurate weight recorders therefore are necessary to guide the driller in controlling this weight. As recognition of the importance of coordinating rotating speeds with the weight on the bit and the type of formation drilled has increased, tachometers that accurately record the rotational speed of the drill stem have become important control instruments on derrick floors.

Recently another drilling-control instrument has been introduced that seems likely to become indispensable for efficient rotary drilling. This instrument records the rates at which the bit penetrates the various formations, gives valuable information on bit design and service, and furnishes data useful for correlating the formations drilled.

### PREVENTION OF CROOKED HOLES

The avoidance of crooked drill holes becomes increasingly more important as wells are drilled deeper. Drilling problems are multiplied in their complexity when drilling is carried to great depths if the hole above the drill bit is not straight; twist-offs of the drill pipe occur frequently; fishing jobs are numerous and costly; and great difficulty often is experienced in "running" casing into wells that deviate irregularly from the vertical. Moreover, casing frequently "hangs up" in a crooked hole and becomes wedged so firmly that it cannot be lowered or withdrawn. Small casing then must be run to bottom through the wedged pipe, making one more string of casing in the hole than ordinarily would have been required. Many crooked holes also cannot be straightened successfully by redrilling or sidetracking and have to be abandoned.

Crooked-hole troubles do not end when the wells are "placed on production"; if the wells flow naturally, the crooked-hole production problem is deferred temporarily, but as soon as it becomes necessary to pump the wells, the operator again is made to realize that more care in drilling might have eliminated many later pumping problems. Often tubing can be placed in crooked wells only with difficulty; and even when no undue difficulties are experienced in running tubing in wells that are not straight, tubing strings in crooked wells must be replaced frequently along with the sucker rods that actuate the pumps. The more crooked the well, especially if sand is produced with the oil, the more often must the tubing and rods be replaced. More power is required to pump oil from crooked wells, and frequently larger pumping units must be installed than would have been necessary for pumping equal volumes of oil from the same depth in straight wells. For these and other reasons lifting costs in crooked wells often are excessive and far above the average for comparable production from straight wells of similar depths.

For many years it was thought that straight holes could be drilled only at slow rates of advancing the bit with minimum weight on the bit and low mud-fluid circulating pressures. When the depths to which wells were drilled increased and drilling speeds greatly in excess of those used in drilling shallow wells became desirable, it was learned, however, that straight holes could not be drilled without concentrating great weight immediately above the bit so that the drill pipe would be in tension during drilling. At deep-drilling operations, therefore, drill-collar assemblies ranging up to 360 feet in length now are inserted in the drill stem above the bit to provide the weight necessary to prevent the bit from deviating from a vertical course. That concentration of weight near the bit and high rotational speeds of the drill stem will result in the drilling of straight holes is demonstrated by the experience of many operators who have been enabled thereby to drill deep wells at no point deviated more than one-half of 1 precent from the vertical.

*Directional drilling.*—The experience acquired in drilling straight holes has proved invaluable where wells purposely are drilled at an angle from the vertical to intercept deep-seated oil-bearing formations hundreds of feet laterally from a point vertically below the derrick floor. "Slantwise" or controlled directional drilling now has a definite place in oil-field development in many areas where it is impossible for one reason or another to erect a derrick directly above the region of the producing sand from which it is desired to drain oil. Many oil leases under the Pacific Ocean opposite Huntington Beach, Calif., are being developed by wells drilled on sites several city blocks from the shore line, and in the Wilmington-Long Beach area, Calif., directional drilling has made it possible to tap productive sands under industrial plants, harbor channels, schools, and industrial sites reserved for future use from drilling sites on adjacent lands. The numerous faults in some areas of the field also have made it advisable and economical to drill holes "off vertical" and drift them across the fault planes. Furthermore, certain operators in the Wilmington field also found it most economical to develop the three producing sands in the field by drilling three directed wells from one surface location.

The course of a directionally drilled hole is maintained by frequent surveys that show not only deviation of the hole from the vertical but also its drift in a direction from an established reference line. The accuracy with which a well now can be drilled to tap formations a thousand or more feet laterally and thousands of feet below the elevation of the derrick floor indicates the great strides made in recent years in perfecting well-survey instruments and surveying technique, and in slant-hole drilling practice.

*Horizontal drilling.*—For many years the only practical method for developing oil fields was to drill boreholes directly downward from the derrick floor into the underlying oil-bearing formations. Later, there was need, in some oil-producing areas, to develop and produce pools or parts of oil pools that could not be tapped by drilling vertical boreholes, therefore slant-hole drilling was developed to make possible the production of oil from regions beyond the confines of the vertically downward extended boundaries of the properties on which the boreholes were started. Recently the drilling of horizontal boreholes radially outward from a central shaft has been suggested as a means of developing commercial oil production from sands of low saturation in shallow and partly depleted fields.

According to Ranney,[31] a proposed method for developing an oil pool by horizontally drilled wells consists of sinking a 6- to 8-foot-diameter shaft from the surface of the ground through the oil-bearing sand, enlarging the shaft into a chamber 20 feet in diameter opposite the sand, and drilling horizontal holes (as many as 16) from the circular chamber radially outward in the more productive parts of the oil-bearing formation. In the proposed method the working chamber, with a sump at the bottom, is to be lined with concrete and the first 100 feet of each horizontal well drilled therefrom is to be cased with 4- or 5-inch-diameter pipe cemented through the chamber walls. The pipes are to extend into the chamber where each will be fitted with a valve. If gas still is present in the sand, or if large quantities of water are developed, drilling is to be continued through stuffing boxes on the ends of the pipes. It is proposed to conduct the gas from the borehole to the surface of the ground through pipes connected to the well casings on the "drill-bit side" of the stuffing boxes; likewise, it is proposed to draw water and cuttings from the boreholes through pipes connected to the underside of the well casings.

In the proposed method, drilling is to be done with core barrels and the courses of the boreholes are to be noted by frequent surveys to indicate when the bits should be directed upward, downward, to the right or to the left to keep the boreholes within the proper oil-bearing stratum. Ranney[32] states that the lengths of the horizontal boreholes may be 2,000 or more feet depending on the distance to the property lines and the strength of the drilling machines. Accord-

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[31] Ranney, Leo, The First Horizontal Oil Well: Petrol. Eng., June 1939, pp. 25–30.

[32] Ranney, Leo, Work cited in footnote 31, p. 30.

ing to the plan, the boreholes when completed are to be shot to within 200 feet of the shaft to enlarge their bore.

Ranney estimates that the maximum cost of developing a tract of 600 to 800 acres when the producing sand is approximately 500 feet from the surface of the ground will be $400 per acre, and oil-lifting costs are not expected to exceed $1 per barrel for many years after the development of a tract is completed.

Although the tentative method of Ranney for developing shallow oil sands has not been carried out in the field some aspects of the practicability of drilling horizontal holes have been demonstrated, and the first horizontally drilled well has produced 350 barrels of oil a day.[33] This well was drilled horizontally into an outcrop of the First Cow Run sand in Havener Run, Morgan County, Ohio, to save the cost of sinking a shaft. The tract developed by the well contained 61 acres on which 46 vertical wells had been drilled and abandoned after oil no longer could be produced from them at a profit. The experience gained in drilling and producing the pioneer horizontal well suggest further work on horizontal-drilling methods in other partly depleted fields in the Eastern States where early production methods left much of the oil in the shallow sands. As with oil-mining methods generally, the price for oil will be a controlling factor in justifying the initial and operating expenses for sinking shafts drilling horizontal wells, and producing oil from them.

### "SLIM-HOLE" DRILLING

The drilling of smaller-diameter boreholes than usual ("slim-hole" drilling) has been carried on to some extent in wildcat exploration during the past 2 or 3 years. Now, the practice of drilling small-diameter holes for regular development of oil fields where drilling conditions are favorable is growing rapidly. Throughout many areas of the United States operators have come to the conclusion that, for a long time at least, wells capable of producing large volumes of oil currently will not be permitted to flow at maximum rates. Operators in the Panhandle area of Texas especially are convinced that wide-open production definitely is a practice of the past and that small-diameter producing strings are adequate for the small per well allowables that wells will be permitted to produce for some time to come. Accordingly the trend in that area, and to a growing extent in the Mid-Continent and Gulf Coast regions, is to reduce the diameter of drill holes and to case them with smaller diameter pipe than has been customary in the past.

Although slim-hole drilling is the extreme of this trend, C. C. Anderson, petroleum engineer, Bureau of Mines, Amarillo, Tex., in a communication to the writers reports that an increasing number of portable rotary drilling outfits is being used in the Panhandle of Texas and surrounding oil fields. The outfits—drilling engine, draw works, rotary table, and pumps—are mounted on a motor-driven truck; a mast usually is employed instead of a derrick, tubing is used for drill pipe, and oil is circulated in place of mud fluid to bring the drill cuttings to the surface of the ground. Surface casing is 8⅝ inches in diameter, and production strings are 4½ inches in diameter. The wells usually are shot with nitroglycerin, then cleaned and washed with special equipment. Formerly with standard rotary tools an average of 14 days was required to clean out a well after shooting. The newly adopted procedure requires only 48 hours. The slim-hole technique has reduced the time for drilling to depths of 2,100–2,300 feet to about 12 days; the clean-out period has been shortened from about 14 to 2 days; drilling and casing costs have been lowered, and the drilling crews have been reduced from five men to three. On the whole, the cost per well has been reduced almost one-half, yet the well potentials are nearly as great as they are for holes of larger size.[34]

Favorable as the new technique of drilling may seem, certain economic disadvantages appear as clouds on the horizon if the practice becomes widespread. Such a material reduction in cost of drilling and equipping wells will tend to increase the number of oil wells drilled and undoubtedly result in further reduction in per well allowables. This in turn may cause serious financial difficulties, especially in connection with operations of the older and more costly wells that have not been allowed to produce enough oil to pay for their cost and operation.

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[33] National Oil Derrick, Oct. 2, 1939, p. 6.

[34] In the Gulf Coast region the cost of small holes from 5,000 to 8,000 feet deep is about $2 per foot: World Petrol., June 1939, p. 96.

## MARINE DRILLING

The recent extension of oil-field activities into marshlands, shallow-water areas, inland lakes, and open waters of the Texas and Louisiana Gulf coast has led to many innovations in drilling and production practices. Many drilling sites are in extensive swamps and marshes that are not easily accessible and hinder the moving of heavy equipment; some are in areas under 1 to 2 feet of water so that canals must be dredged in order that derrick materials and drilling equipment can be transported to the well sites; others are in inland lakes where the water is 6 to 10 feet deep; and recently, derricks have been erected in the open waters of the Gulf of Mexico.

Striking examples of what can be accomplished under adverse conditions are shown by the types of foundations constructed at marine drilling sites. In marshes, and lands submerged under shallow depths of water, various designs of wooden mats and superstructures costing up to $12,000 usually are adequate for drilling-site purposes. Mat foundations are designed to cover large enough areas so that the unit load on the mats is within the limits of the bearing capacity of the soil on the bottom of the marshes. Superstructures, consisting of timbers laid as cribbing or fabricated into structural forms, distribute the equipment loads uniformly over the mats.

In shallow inland lake areas and to a great extent in the open waters of the Gulf of Mexico where the water is too deep for mats, drilling sites usually are constructed on wood piling.[35] [36] Wood piling also is used to support derricks in relatively shallow water offshore from the coast of California. One operator in the Gulf Coast area uses piling only for the derrick and pipe rack and mounts the mud-fluid-circulating pumps, mud pits, and boilers on floating barges; others support all the drilling equipment on piling. The cost of structures erected on piling ranges from $20,000 to $70,000.

Because of the great depths of the water in the offshore area of the Elwood field in California and the abrasive action of waves and sand, most of the derricks used in marine drilling in that field are erected on concrete piers, and wood piling is used only to support the runways between the derricks and the shore. Some of the derricks in the Elwood field are supported on individual, large-diameter, reinforced concrete piers with internal steel piling, and others are erected on a base supported on four steel cylinders filled with concrete about a central concrete-filled steel cylinder with a steel-lined hole in the center through which the well is drilled.[37]

Probably the outstanding development in marine drilling practice in the Gulf Coast area, where operations are carried out in 6 to 10 feet of water, is the use of submersible steel barges.[38] The barge unit usually consists of two steel flat-bottom hulls adequately braced, reinforced on the inside, and tied together in such manner that clearance between the hulls is provided for the wellhead fittings when the well is completed and the barge unit is moved to another drilling site. The barge is towed into position and submerged by opening sea cocks until it rests on the floor of the bay with the deck above the water line. The unit then is secured firmly to piles. A superstructure erected on the barge supports a standard 136-foot steel derrick, drawworks, electric motors, and equipment for drilling. The derrick floor is 11 feet above the deck of the barge, and the mud-fluid-circulating pumps, mud tanks, and other auxiliary equipment are placed in the space under the derrick floor. A floating barge houses the Diesel-electric or gasoline-electric power-generating unit in addition to an office and sleeping quarters for the engineer and geologist.

In general, after the drilling site has been prepared, marine drilling operations differ little from those on land, with the possible exception that greater precautions are taken to prevent pollution of the water about the well site by mud fluid and oil than ordinarily are necessary when drilling on dry land. However, the additional expense of preparing derrick sites or providing drilling barges and equipment, tug boats to tow barges loaded with pipe, cement, and other materials to the drilling site, launches to transport the crew to and from their work,

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[35] Herbert, W. F., and Anderson, H. E., Foundations for Marsh Operations: Am. Petrol. Inst., Drilling and Production Practice, 1937, p. 347.

[36] Alcorn, J. W., Marine Drilling in the Gulf Coast: Am. Petrol. Inst., Drilling and Production Practice, 1938, p. 40.

[37] Denham, C. M., Rig Construction for Ocean Drilling: Am. Petrol. Inst., Production Bull. 208, 1931, p. 114.

[38] McBride, G. I., Drilling Barges: Am. Petrol. Inst., Drilling and Production Practice, 1935, p. 40.

or housboats in which living quarters are maintained for the crew requires practice of extreme economy if marine drilling is to compete with land drilling in developing oil at present prices for petroleum and its products.

### MUD-FLUID CONTROL OF FORMATION PRESSURES

Although methods of controlling well pressures have been improved rapidly in recent years, premature blow-outs at drilling wells still occur occasionally where proper precautions are not taken. Most progressive operators, however, install pressure-control equipment, such as bradenheads, master gate valves, and blow-out preventers, to cope with exceedingly high pressures incident to deep drilling, and wells so equipped seldom get out of control.

Recent developments in controlling the weight and viscosity of drilling mud fluids and in reconditioning and degassing the drilling muds also have contributed materially to reducing the hazards of blow-outs. Although high-density muds have been necessary to control well pressures in many areas, Carpenter[39] has pointed out that normal formation pressures can be controlled with a margin of safety and blow-outs prevented while wells are being drilled in by circulating mud fluid weighing only approximately 75 pounds per cubic foot. The use of very heavy mud fluid is not always necessary to prevent blow-outs, but proper conditioning of the fluid is essential. At a depth of 10,000 feet a column of mud weighing 75 pounds per cubic foot exerts a pressure at its base of about 5,200 pounds per square inch, which is sufficient to overcome the usual pressures at that depth in wells. However, if formation gas becomes mixed with the mud fluid in the well, the mud fluid must be reconditioned as rapidly as it becomes "gas-cut" to maintain its proper consistency. So important is the avoidance of gas cutting of mud fluids that a method whereby the mud fluid continually is examined as it issues from the flow line was developed recently. The method indicates increasing concentration of gas and thereby makes it possible to anticipate the approach of the drill to high-pressure horizons that might cause gas-cutting of the fluids and lead to unexpected blow-outs.

Bottom-hole pressures in deep-seated formations producing oil and gas generally approximate the equivalent hydrostatic head of salt water—computed roughly as the hydrostatic head of fresh water plus about 7½ percent. Therefore, in a typical water-drive field producing from a depth of 7,000 feet, expected bottom-hole pressures normally will be about 3,200 pounds per square inch. Abnormal pressures, however, frequently are found in certain wells. In the Clinton field, Tex., for example, an indicated bottom-hole pressure of 6,200 pounds per square inch was recorded at a depth of 8,800 feet—almost 50 percent above that normally expected—and in a wildcat well near Abbeville, La., the indicated bottom-hole pressure of 8,000 pounds per square inch was 45 percent greater than the expected pressure at a depth of 12,216 feet.

One of the highest bottom-hole pressures found at a depth of 10,000 feet was recorded in the South Crowley field, La., where the indicated bottom-hole pressure was 7,700 pounds per square inch or 77 pounds per square inch per 100 feet of depth—equivalent to the pressure at the base of a column of mud fluid weighing 110.7 pounds per cubic foot.

A primary factor in successful rotary drilling is proper functioning of the mud fluid, and some of the important achievements of modern deep drilling are the result in part of recent improvements in methods used in rotary drilling to condition mud fluids and control their physicochemical properties.

Mud-fluid control involves balancing the colloidal characteristics of mud fluids with their density, viscosity, and wall-building properties. An ideal mud fluid has enough weight to overcome the pressures in the formations penetrated by the bit; viscosity such that cuttings will be removed from the cutting edges of the bit as fast as they are formed, held in suspension until they are circulated out of the well, and then dropped out of the fluid into the "mud ditch"; and wall-plastering and colloidal properties that result in building on the walls of the hole of the thinnest mud sheath that will prevent caving of the walls, yet one thick enough to prevent material loss of drilling water to the surrounding earth formations and at the same time keep undesired fluids in their respective strata.

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[39] Carpenter, Chas. B., Some Causes of Blow-outs During Drilling and Means of Prevention: Bureau of Mines, Inf. Circ. 6938, 1937, 27 pp.

In recent years increasingly more attention is being given to control of viscosity of mud fluids by the addition of chemicals and to maintenance of their optimum colloid content by the addition of colloidal materials, such as bentonite. Drilling fluids of native clay deficient in colloids are treated in this way to decrease the permeability to water of the mud sheaths formed in wells. It has been learned also that the high formation temperatures in deep wells not only increase the viscosity of mud fluids but the higher the temperature the greater the quantity of drilling water that will filter in a given time through the mud sheaths formed in the well. As the thickness of mud sheaths in wells is approximately proportional to the rate of filtration of water through them and very thick mud sheaths are not desirable, greater quantities of bentonite are added to drilling fluids when subsurface temperatures are high, so that a thin, relatively impervious, mud sheath will form on the walls of the hole.

When mud fluids made from clays and water are too light in weight to provide enough hydrostatic head to overcome formation pressures in deep boreholes and to prevent fluids from high-pressure sands from entering the holes, weighting material, chiefly barite,[40] is added to give the mud fluids proper weight. The addition of barite to ordinary mud fluids weighing 70 to 85 pounds per cubic foot increases the weight of the fluids to 125 or more pounds per cubic foot, which is adequate in a 10,000-foot borehole to overcome formation pressures greater than 8,000 pounds per square inch.

Effective control of drilling fluids becomes increasingly important as wells are drilled to greater depths; and careful supervision over their physical properties is necessary, particularly where there is danger from high-pressure sands or formations that slough and "heave" into the borehole when wetted by water. Accordingly, scientific control of mud fluids during drilling is being practiced to an increasing extent at many wells, especially those being drilled to great depths. At such drilling operations, chemists and "mud engineers" are constantly at hand to test samples of the mud fluid to determine its weight and viscosity, wall-building properties, and other characteristics (such as the hydrogen-ion concentration and its shear strength) with special mud-testing apparatus that has been devised for making rapid tests at the wellsite where suggested recommendations can be acted upon immediately.

### DRILLING HEAVING SHALES

Perhaps the most troublesome problem in certain areas is how to drill through strata of shales that heave and slough into the hole in the course of drilling when exploring for oil at great depths. Its gravity is startlingly evident when it is considered that in some drilling operations up to $125,000 has been expended for mudding materials alone to "fight" heaving shales, and that some boreholes which ordinarily should have been drilled for less than $100,000 actually cost $250,000 and then did not become commercial oil producers. The cost of tools lost in boreholes when shales heave and "run" into the holes and the expense of efforts to recover them, in addition to the expense for drilling mud, make these ventures exceedingly costly.

Heaving shales are particularly troublesome in an area about 100 miles wide extending along the Texas-Louisiana coast. Heaving shales have been found also in some wells in California, and it is not unlikely that they will be reported in other parts of the United States when deep wells are drilled. Intensive studies of the heaving-shale problem are being conducted by engineers and operators vitally interested in drilling wells successfully in areas where shales heave and interfere with drilling operations. After several years' study some students of the subject are fairly well convinced that shales heave because of phenomena attending hydrous alteration of the shale by water from the drilling fluid (causing sloughing of the shale into the drill hole in excess quantities), and because of excessive differential pressure between the gas-carrying shale and the hydrostatic head of the mud fluid (allowing gas to expand and break the shale, which heaves into the well).[41]

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[40] In 1938, 126,697 tons of ground barite were used in oil-well drilling in the United States: Bureau of Mines Minerals Yearbook, 1938, p. 1327.

[41] Baker, Chester L., and Garrison, Allen D., Chemical Control of Heaving Shale: Oil Weekly, February 6, 1939, p. 21.

All shales found in drilling for oil and gas do not heave and cave when drilled and wetted by water; those subject to hydration are bentonitic[42] in character and display a great affinity for water, which causes them to swell and disintegrate. Some varieties, when wetted by water, expand to more than four times their original volume.

When a bentonitic shale is penetrated by the drill and is wetted by the water in the drilling fluid it begins to slough and cave into the borehole. Sloughing and caving continue until caving becomes a mass movement, and the shales "heave" into the borehole—sometimes filling the hole for hundreds of feet and sticking the drill stem.

Field and laboratory investigations suggest that one solution of the heaving-shale problem lies in finding some means of drilling through the shale strata without wetting the shales by water to the point where they reach the caving stage. It has been considered, therefore, that the problem might be solved by mechanical means, chemical methods, or possibly a combination of the two.

As frequent stoppage of mud-fluid circulation in boreholes when drill pipe is inserted and withdrawn introduces a hazard during the drilling of heaving shales charged with gas and because the tendency for shales to heave is aggravated by the swabbing action on the walls of the hole when drill pipe is pulled out of the borehole, engineers have concluded that changes in drilling practice might permit successful drilling of wells through heaving shales.

Working on the thesis that heaving shales could be penetrated with minimum difficulty if the need for withdrawing the drill pipe could be eliminated and continuous circulation of mud fluid maintained with the drilling bit continually rotating on bottom except when changing bits, engineers attacked the problem with those mechanical requirements in mind. The need for withdrawing the drill pipe to change drilling bits was overcome by using collapsible-type wire-line bits and flush-joint casing for drill pipe.[43] Continuous circulation of mud fluid was accomplished by using special full-hole continuous-circulation tool joints; and by taking every precaution to prevent interruptions to the continuous operation of the machinery and equipment on the derrick floor the drilling bit was kept rotating on bottom except for short periods when it was necessary to change bits.

The use of sodium silicate (water glass) in drilling fluids also has been a valuable aid in drilling heaving shales. Sodium silicate forms a gelatinous film on the shale surfaces that prevents the shale from becoming wetted by water. Sodium silicate not only renders mud fluids inert to all types of heaving shales but materially improves the gel and wall-building properties of the mud fluids to which it is added.[44] Concentrations of sodium silicate used range from 30 to 60 percent, depending on the character of the shale being drilled and the quantity of colloidal material in the mud fluid.

Mud fluids made of clays and brines also have been used by some operators in drilling heaving shales. Although mud fluids composed of clay and brine are inferior in wall-building properties to mud fluids made with fresh water, brine-mud fluids seem to prevent bentonitic shales from swelling and for that reason are being used with some success in combating heaving shales. Best results seem to be attained when drilling-mud fluids are mixtures of clays, brine, and sodium silicate. Such fluids, however, are costly, and control of their physical properties during drilling operations requires constant attention of technicians versed in colloidal chemistry to obtain optimum success. Proper control of the density of drilling fluids is essential when drilling is done in heaving shales charged with gas under high pressures, and to overcome the high pressures at many Gulf coast operations, weighted mud fluids weighing as much as 140 pounds per cubic foot (18.7 pounds per gallon) often have been used.

Although great strides have been made toward developing methods that will enable the driller to penetrate heaving-shale strata in the minimum time and at

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[42] The name "bentonite" has been applied to a group or series of clay-like materials characterized by an alkaline oxide and alkaline earth content of 5 to 10 percent, fine grain size, high absorptive powers, and usually very strong colloidal properties. See J. C. Conley, Bentonite: Its Properties, Mining Preparation, and Utilization; Bureau of Mines Tech. Paper 609, in press.

[43] Sclater, K. C., Casing Used as Drill Pipe to Overcome Heaving Shale: Petrol. Eng., February 1939, p. 25.

[44] Sullins, C. A., and Van Dyke, Orien, Methods That Drilled Heaving Shale to 13,728 feet in Agua Dulce Field: Oil Weekly, January 23, 1939, p. 52.

minimum expense, the operator still has no assurance, however, when the drilling bit meets heaving shale in the borehole that the shale strata can be drilled successfully and the hole extended into the underlying potential oil-bearing formations. Intensive research in the field and laboratory, concentrated on still more dependable methods than are now available for overcoming the heaving of shales met in drilling for oil, therefore must be continued to the end that obstacles seemingly insurmountable today can be overcome successfully and the vast store of oil in sands underlying shales that heave when wetted by water made available to the army of consumers.

### LOGGING BOREHOLES ELECTRICALLY

Within the past few years an electrical method of logging subsurface formations in oil wells has been used extensively in many fields. Electrical logging consists of measuring the electrical resistivity and electrical porosity of formations penetrated by a drillhole by means of a device lowered into the hole on a cable containing insulated conductors. A current of constant intensity is transmitted through the ground, and by means of recording mechanisms connected to the electrical circuit the electrical resistivity of the rock (the reciprocal of the conductivity) is measured. The log chart obtained as the electrode is lowered into the borehole constitutes a continuous record of the resistivity of the strata in that part of the hole under examination. Electrical porosity measurements of formations (not a direct measure of the ability of the rock to hold oil but useful for correlating similar records taken in adjacent wells) are obtained by means of spontaneous currents generated in the drillhole. The spontaneous currents result either from infiltration of the drilling-mud fluid into the porous strata or contact of the water filling the hole with the fluid contained in the formation. The currents thus generated are most intense opposite the pervious layers, therefore the porosity log shows peaks opposite sand formations and flat curves opposite less pervious beds. Both the resistivity and electrical porosity diagrams are recorded simultaneously. As the diagrams are obtained directly at the well, results can be interpreted immediately after the survey.

When correlated with a graphic log of known formations the information obtained by electrical logging gives a complete record of formations penetrated in a new hole. Electrical logging surveys usually are made in an uncased hole, thus making this method applicable chiefly to rotary-drilled wells, but instruments have been developed recently whereby an electric method can be used also to log formations surrounding wells lined with pipe.

### CORING PRACTICES

*Mechanical coring.*—Drill cuttings washed from the circulating mud fluid during drilling and drillers' conclusions based on the "feel" of the bit no longer are depended on entirely to give information on the character of the formations and their respective positions in the structural column. More definite and exact information concerning the physical characteristics and positions of the formations penetrated by the drill than those observations afforded now are considered essential for successful completion of deep wells. Electrical coring has gone far in giving operators a "picture" of the formations penetrated, their relative position in the structural column, and their relative porosities and permeabilities. Electrical logs, however, useful as they are for correlating and other purposes, do not furnish data on absolute porosities and permeabilities or on the saturation of fluids in the formations. Thus operators must resort to coring and bringing specimens of the formations penetrated by the drill to the surface of the ground to give all the information needed for successful completion of wells. Coring, therefore, has become routine procedure at most deep rotary-drilling operations.

In wildcat and exploratory drilling continuous cores of formations penetrated by the drill, almost from the "grass roots," usually are taken. In developed areas, however, where the stratigraphy of the subsurface strata is fairly well worked out, coring ordinarily is employed only to determine suitable casing seats and to bring core specimens of the producing formation to the surface of the ground for laboratory determinations of its oil and water content, porosity, and permeability—all of which are needed in planning optimum well-completion methods. Mechanical coring is being improved constantly, and as wells are drilled deeper coring is becoming an indispensable aid to successful drilling. By improvements in the design and quality of core cutters (coring bits), cores 10 feet in length and about 2½ inches in diameter can be cut in almost any formation penetrated during rotary drilling. Longer core barrels than were used a few years ago and improved core catchers not only permit taking long cores, but the resultant higher efficiency of core recovery has reduced the number of round trips of the drill pipe in and out of the hole per foot of core recovered. In fact, boreholes now can be cored and footage made with a core bit almost as rapidly as when drilling was done with a solid-type bit. The practicability of core barrels to take cores at any depth so far reached by the drill was demonstrated in the Wasco field, Calif., where the upper part of a 15,004-foot hole was cored at intervals and the last few hundred feet cored continuously.

*Wire-line coring:* Wire-line coring recently developed to eliminate frequent pulling of the drill pipe when deep wells are being cored, is used extensively in areas where the producing formations are sands. In wire-line coring, full-hole drill pipe is used, and the core barrels are dropped into the drill pipe and pumped down to be seated in the cutter barrel. After a core is cut a small socket attached to a wire line is run in the drill pipe to "fish" out the core barrel. Thus, in wire-line coring a core is cut and recovered without removing the drill pipe from the hole. As the drill pipe is withdrawn from the hole only when the large cutter shoe attached to its lower end becomes too worn for further use, requiring replacement, 50 to 150 feet or more of formation can be cored without withdrawing the drill stem and with little delay to actual drilling operations.

*Side-wall sampling:* Continuous coring of drill holes is not always necessary, especially when a borehole has been electrically logged, and to reduce the time required for getting the information needed for efficient completion of wells, less expensive methods for acquiring the desired data constantly are being sought. Inasmuch as progressive operators usually have electrical surveys made of the boreholes before placing casing the expense for determining the productive sections of a sand can be reduced materially by coring only those sections of a sand zone that electrical surveys indicate are porous enough to contain fluids and permeable enough to permit them to flow into the well.

A method developed recently to make continuous coring unnecessary and thereby reduce the cost of coring bore holes, yet furnish the operator the information he needs, is the taking of formation samples by means of side-wall samplers lowered into the drill hole on the cable previously used to log the hole electrically. According to Leonardon and McCann[45] the side-wall sampler is similar in principle to the gun perforator described in a later section of this report. In taking formation samples the gun barrel is lowered into the bore hole, and bullets having the shape of hollow cylinders are fired by means of individual powder charges into the side walls of the hole. The powder chargse are ignited by means of electrically heated wires. The hollow cylinders serve as core barrels and are attached to the gun barrel by two lengths of wire by means of which the bullets and enclosed cores can be retracted from the formation into the bore hole. Gun barrels have a capacity of 6 or 18 bullets, and each bullet is fired separately. The cores are ¾ inch in diameter and 1½ to 2½ inches long, ample in size for usual porosity, permeability, and other analyses.

Hydraulically operated side-wall samplers run into the drill hole on the end of drill pipe also are used to obtain samples of wall formations in open holes to confirm information obtained during regular drilling and coring or to check information acquired by electrical coring methods. In taking samples, after the coring tool has been lowered to the desired depth in the bore hole, pump pressure is applied to the mud fluid in the drill stem to actuate a piston in the body of the tool which forces two guide blades fitted with pairs of core-taking tubes into the side walls of the hole. When the weight of the drill stem is placed on the tool the core-taking tubes are forced into the side walls and filled with samples of the formation. The sampler then is withdrawn from the hole, and the formation specimens are extracted from the tubes and taken to the laboratory where their physical properties are determined.

Hydraulic wall samplers run on 3½-inch drill pipe take samples $\frac{7}{16}$ inches in diameter and 1¼ inches in length; ½- by 1½-inch samples are taken by samplers run on 4½-inch drill pipe; ⅝- by 2-inch samples when $5\frac{9}{16}$-inch drill pipe is used; and $\frac{11}{16}$- by 2½-inch specimens when 6⅝-inch drill pipe is used to lower the

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[45] Leonardon, Eugene G., and McCann, D. C., Exploring Drill Holes by Sample-taking Bullets: Am. Inst. Min. and Met. Eng., Technical Publication 1062, Petroleum Technology, May 1939, 13 pp.

sampler in the bore hole. Four samples are obtained per round trip of the sampler.

Although side-wall sampling is a relatively new technique in formation-sampling practice, it has demonstrated its usefulness, especially when employed in conjunction with electrical logging, in providing practical means for securing geologic and other information on the strata penetrated by bore holes.

Pressure coring is discussed in a later section of this report.

## TRENDS AND PRACTICES IN WELL COMPLETIONS

Notable improvements and significant developments in well-completing equipment and methods not only have increased the production efficiency of wells but have made possible deep-well completions that would have been impracticable a few years ago. Recent advances in the development of instruments and technique for acquiring reservoir data and interpretations of reservoir conditions from such data now make possible the determination of completion procedure to obtain optimum recovery of oil. In some fields of the Gulf coast, for example, the inherent problems of completing deep wells are complicated by the fact that the productive formation not only comprises a relatively thin section of the formations penetrated by the well but is overlain by gas-bearing and underlain by water-bearing strata. As a result, exclusion of the water- and gas-bearing formations and inclusion only of the oil sand in the section to be opened to the well is the basis for completing many of the wells. This is done by what is known as selective perforation—a method of completing wells made possible by development of the gun perforator.

In completing a well that is to be gun perforated later, a full-gage hole is drilled and blank casing run to bottom and cemented. The casing then is selectively gun perforated opposite the oil sand, thereby excluding the gas and water zones from the well. Gun perforating permits great flexibility in testing different productive levels, and if troublesome or undesired zones are opened to the well inadvertently or otherwise they can be cemented off at any time and new perforations shot through the casing above or below those plugged with cement because they were incorrectly placed.

The gun perforator consists essentially of a series of short gun barrels from which steel bullets are shot to puncture the casing wall and the surrounding cement jacket. The gun is lowered into the hole to the required depth on a wire line and fired electrically from the derrick floor. Accurate well-depth measurements[46] are essential to complete wells successfully by selective perforation. For that reason, recent refinements in well-measuring devices and methods have contributed in large measure to the satisfactory completion of selectively perforated wells. To "spot" the perforator at the proper depth in the well the gun is lowered on a wire line or on the same cable used in taking an electric log of the well, and measurements of the length of line run into the hole are made by devices calibrated against measurements made of the drill pipe under stress.

Positive perforation of casing at the desired depths in wells without splitting the casing, fracturing the surrounding cement, or breaking the bond between the cement and casing or between the cement and the formation was a problem of vital concern to oil producers until the gun perforator was introduced. However, this device—first used in 1933—solves the problem successfully; it provides not only a rapid and effective means of perforating casing in new wells at a predetermined depth but has aided greatly in developing formations in old wells which, for one reason or another, originally were not opened to production.

The use of recently developed drillable metal liners and perforated sections in oil strings permits greater flexibility in well-completion technique than heretofore has been possible with regular steel pipe. Liners of drillable metal are strong enough to meet all well-service requirements yet have certain physical properties that permit them to be "drilled up" and the cuttings removed from the hole by the circulating mud fluid.[47]

One of the most common uses for drillable metal pipe is in production liners for wells in which upper, less productive oil sands are "passed up" temporarily to produce from lower, more prolific oil-bearing zones. The liner used for such

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[46] Reistle, C. E., Jr., and Sikes, S. T., Jr., Well-Depth Measurements: Am. Petrol. Inst., Drilling and Production Practice, 1938, p. 80.

[47] Hammer, O., Applications of Drillable Material for Well Completions and Repair Work: California Oil World and Petrol. Industry, April 1939, 2d issue, p. 14.

purposes is composed of blank sections of drillable pipe opposite the upper sands, blank sections of steel pipe opposite the nonproductive formations, and a perforated section of drillable pipe opposite the lowest zone from which production is to be made. When that zone is depleted of its recoverable oil the perforated section is ground up with a wall scraper, and the hole opposite the depleted sand is filled with a cement plug. The next higher section of drillable liner then is drilled out, the sand exposed, and the oil produced through a secondary screen set inside the steel liner. When that sand is depleted of its recoverable oil the next higher sand is opened to production, and so on until all the sand zones penetrated by the borehole have been exposed and produced.

The use of magnesium-alloy pipe is another innovation in oil-well completion technique. Magnesium-alloy pipe is completely soluble in hydrochloric acid, and when sections of pipe of this material are used to blank off upper oil-bearing sands they can be removed later by acid and the sands exposed for production.

The need for finding producing horizons in boreholes and determining the most prolific oil-producing section of an oil zone has led to the development of a formation tester by means of which the capacity of the well to produce oil and gas can be determined for each foot of hole. Formation testers are run into wells on drill pipe, and by means of packers the formations above the strata to be tested are excluded from the test. Measurements of the volumes of fluids reaching the surface through the drill stem indicate the producing capacity of the strata below the packers. Data acquired through the use of formation testers in conjunction with subsurface pressure data furnish the operator with valuable information on the fluid content and productivity of the oil- and gas-bearing horizons in his well.

Experience gained in drilling and completing deep wells shows the need for better grades of casing than now are obtainable, and the industry has proposed that manufacturers of pipe establish the minimum yield point of casing for deep wells at 80,000 pounds per square inch. Casing of this minimum strength should prevent many of the difficulties caused by the parting of long strings of casing when they are being placed in wells. A considerable amount of study also is being given to the design of casing joints, and already the trend in the oil fields is toward using internal upset casing that increases the strength of threaded joints 15 to 50 percent. According to Strang,[48] a new development in casing is the bell-and-spigot-type joint with coarse threads designed for high pull-out strength and a bead welded around the joint to prevent leakage.

To reduce the weight and cost of long strings of casing, tapered-weight casing strings (strings consisting of sections of casing of the same external diameter but of different internal diameters) are beginning to be used in deep wells. One company recently used five different weights of 7-inch O. D. casing in a well completed below 10,000 feet in the Coles Levee field, California. According to Alcorn,[49] the 7-inch oil string in this well is made up of 3,200 feet of 30-pound Grade D casing; 800 feet of 30-pound Grade C; 1,100 feet of 28-pound Grade C; 1,800 feet of 26-pound Grade C; and 3,300 feet of 24-pound Grade C casing. In general the lower section of the oil string contains the heavier-weight pipe in order that the forces tending to collapse the casing (which exceed the tensional stresses set up in the casing in the bottom section of deep wells) may be overcome successfully. Another arrangement of different-weight casing in an oil string has the lighter weights of casing in the center section between the heavier sizes above and below, thus providing for the manufacturer's recommended safety factor of 2 for collapse and 2½ for tension.

### CONTROLLED-PRESSURE DRILLING

One of the recent important advancements in well-completion practice is known as the controlled-pressure drilling method.[50] The principal difference between this method and conventional rotary practice for drilling through oil zones is that oil or a mixture of oil and gas is used as the circulating medium instead of mud fluid, and the flow from the well is controlled as drilling progresses by the use of special control equipment. By means of a packing ar-

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[48] Strang, William H., Vast Advancements in Deep Drilling Equipment Make 18,000-foot Holes Possible: Oil Weekly, July 31, 1939, p. 176.

[49] Alcorn, J. W., Significant Strides in Deep Well Completion: Oil Weekly, July 31, 1939, p. 138.

[50] Ross, John S., Review of Controlled-Pressure Drilling Method: Petrol. Eng., September 1936, pp. 116–121.

rangement between the casing and the drill pipe the flow from the well during drilling is confined to a closed system of surface lines and tanks.

In drilling in under controlled pressure the object is to maintain the pressure of the circulating fluid at the bottom of the drill hole slightly lower than the pressure in the reservoir so that a flow of oil and gas will be maintained from the formation into the well. Wells completed under pressure control produce oil and gas continually during drilling, and thus the productivity of the producing zone and other pertinent well data may be observed as the sand is penetrated by the drill. Controlled-pressure drilling is particularly adapted for drilling in low-pressure sands, as no mud fluid is used which in ordinary drilling would plaster the walls of the hole and prevent the flow of oil and gas into the well. Furthermore, as mud fluids are not circulated in the well no water can filter into the oil sand and affect its producing ability adversely.

All wells in the northern extension of the Oklahoma City field, Oklahoma, were completed by pressure-control methods; wells also have been drilled in under controlled pressure in the Kettleman Hills field, California, in west Texas, and in New Mexico.

A modification of the controlled-pressure drilling method also has been used successfully for completing wells, particularly in certain Texas fields. The essential difference between the regular and modified methods is that in the latter method the direction of flow of the circulating medium is reversed, and oil is pumped down the casing and returned to the surface inside the drill pipe.[51] The equipment required in this method is portable and inexpensive, and most of the advantages of standard pressure-drilling equipment are realized at materially lower cost.

### WELL-CEMENTING PRACTICES

Among the most important recent technologic developments in drilling for oil and gas are the great improvements in cementing technique for excluding water from oil wells. Deep drilling brought its quota of cementing problems, but they have been met so successfully that cementing long strings of casing at depths of 10,000 and 11,000 feet now is considered routine procedure. Nevertheless, the art of cementing deep wells embodies many details, and neglect of any one may mean an unsatisfactory cementing job or even complete failure.

Not infrequently, in cementing deep wells as many as 3,000 sacks (150 tons) of cement must be pumped under high pressures behind long strings of casing. Furthermore, the cement must be placed before it takes its initial set, which is greatly accelerated in deep wells by the high bottom-hole temperatures. Bottom-hole pressures as high as 5,700 pounds per square inch have been found in deep wells during cementing operations, and bottom-hole temperatures up to 335° F. have been recorded.[52] To meet such conditions of pressure and temperature, special slow-setting high-temperature cements have been developed to allow enough time for pumping the cement-water slurry behind the casing before it takes its initial set. Even with slow-setting cements large-capacity, high-pressure pumps are needed to pump the slurry behind long strings of casing before the cement takes its initial set. As a result of improved equipment and increased efficiency at cementing jobs as many as 2,500 sacks (125 tons) of cement have been mixed and pumped behind 11,528 feet of 7⅝-inch casing in probably the record time of 53 minutes.

Cementing deep wells has demonstrated that proper conditioning of the hole before cementing is essential if the cement behind long strings of casing is to bond properly to the casing and the formation and form a continuous jacket around the pipe. Increased attention therefore is being given to circulating properly conditioned mud fluids before pumping cement slurry to clean the hole of all sand and cuttings and to equalize the weight of the mud fluid through the depth of the hole. In many fields it is common practice to enlarge the section of the hole to be cemented with a rotary well scraper to minimize the possibility of the cement channeling back of the pipe and to assure a continuous wall of cement around the casing. Enlarging the diameter of the hole and scraping most of the mud sheath off the wall of the hole also insure a better bond between the formation and the cement.

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[51] Beckman, F. C., Completing Wells with Reverse Circulation in East Texas: Oil and Gas Jour., Mar. 10, 1938, pp. 45–46.

[52] Mills, Brad, New Cementing Problems Created by Deep Drilling Being Overcome Rapidly: Oil Weekly, July 31, 1939, p. 110.

*Squeeze cementing.*—Among the newly developed cementing techniques used extensively in completing and repairing wells is squeeze cementing.[52a] This process consists of forcing or squeezing cement slurry under high pressure into or against permeable formations either in open hole or through gun perforations in the casing or liners to prevent incursions of water or gas without shutting off the flow of oil into the well. Reduction of gas-oil ratios by squeeze cementing through perforations in casing and liners has proved extremely effective in a number of fields in the Gulf Coast area, where frequently it was necessary to seal off gas strata found in or immediately above oil-producing zones to comply with maximum gas-oil-ratio requirements. So closely associated were the gas and oil strata in many wells that ordinary cementing methods could not successfully seal off one fluid without sealing off the other at the same time, and it was only after squeeze cementing was developed that it became possible to condition the wells so they could meet maximum gas-oil-ratio restrictions and be allowed to produce.

Outstanding success also has attended the use of squeeze cementing in shutting off water in newly completed wells where water in strata above the oil zone had not been shut off and where it was immediately above the top of the oil in the oil-producing sand, in the bottom of the oil zone, or separated from the oil by a thin shale break. Evidence obtained when attempting to reduce gas-oil ratios and shut-off water by squeeze-cementing methods indicates that cement will set against a gas and water sand but will not make a satisfactory bond with an oil sand. In squeeze cementing full advantage is taken of this phenomenon, and as Parsons[53] points out, cement "squeezed" indiscriminately against both oil and gas zones of productive formations shuts off gas and water but not oil.

Squeeze cementing is proving especially effective in many wells in the Wilmington field, California, where oil occurs in three different zones and the blank sections of the casing next larger than the flow string (ordinarily called the liner, although it extends to the wellhead) are cemented between the top and middle zones and between the middle and bottom zones. In carrying out squeeze cementing in the Wilmington field the blank sections between the perforated sections of the liners and above the upper perforations are cemented in three operations from the bottom upward. Five cement retainers are used, two of which act as plugs within the casing, permitting cement "bridges" to be formed. A cementing basket at the bottom of each blank section of liner and an inverted basket above the top of the upper perforations confine the cement to the space around the blank sections of the pipe. After the liner has been cemented a flow string long enough to extend below the middle zone is run into the well. A string of tubing long enough to extend below the bottom of the flow string then is run inside the flow string already in the well, and the space between them is packed off intermediate between the lower and middle zones. A packer also is set immediately below the upper zone between the flow string and the liner. Thus, when the well is placed on production oil from the lowest zone is produced through the tubing; oil from the middle zone reaches the wellhead through the annular space between the tubing and the flow string, and oil from the top zone is produced from the space between the flow string and the liner.

*Multiple-stage cementing.*—To reduce the time required to place cement in deep wells a new cementing technique known as multiple-stage cementing has been developed. In this process cement is introduced in stages behind the casing through perforations at two or more points in the well, making it unnecessary to pump all the cement to the bottom of the well and up around the well casing. In addition to the advantage that multiple-stage cementing has over other cementing methods by materially shortening the time required to place cement back of casing in deep wells—accomplished by dividing the cement into batches and pumping it out of the pipe at different levels—the method also permits "spotting" the cement behind the casing at points where formations are particularly troublesome or where it is necessary to protect shallow horizons for future production.

"*Full-hole*" *cementing.*—Still another recent development in well-cementing practice is that known as "full-hole" cementing, in which a full-gage hole is drilled into the oil sand and lined with a screened or perforated liner of the same diameter as the casing in the upper part of the hole. After the combination string is inserted in the borehole mud fluid is circulated downward through the blank

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[52a] Torrey, Paul D., Selective Exclusion of Fluids from Wells: Paper published at the Mid-Year Meeting of Am. Petrol. Inst., New Orleans, May 18, 1939; see Oil Weekly, May 22, 1939, pp. 26–35.

[53] Parsons, C. P., Squeeze Cementing: Oil Weekly, Feb. 28, 1938, p. 36.

casing and perforated section and up the annular space between the string and the walls of the hole to remove cuttings and cavings from behind the screen or perforated liner. The blank casing then is cemented above the top of the screen or perforated section.

*Determining top of cement behind casing.*—In early cementing practices the height to which the cement rose in the annular space between the casing and the walls of the bore hole was computed by dividing the volume (cubic feet) of mud fluid pumped into the casing to displace the cement slurry by the area (square feet) of the annular space between the casing and the walls of the hole. The diameter of the borehole was assumed to be constant throughout the section to be cemented and equal to the diameter of the bit used to drill the hole. That a borehole will have constant diameter throughout its length is a reasonable expectancy, nevertheless the walls of boreholes frequently cave during drilling, and sections of the hole become enlarged to indeterminable diameters. Also, in some wells cement escapes from the annular space outside the casing and fills cracks and crevices of unknown size that radiate outward for distances that cannot be measured. Thus, the height to which the cement actually rises in boreholes may be considerably less than that calculated, even when an empirical correction factor is applied.

Unless the operator knows the exact position of the top of the cement behind the casing he has no way of finding whether or not all of the desired formations have been "cemented off." Knowledge of the elevation of the top of the cement also is necessary when future perforating jobs and eventual abandonment of the well are being planned.

The position of the top of the cement in the annular space behind the casing in a borehole now can be determined accurately by making a geothermal survey of the hole with subsurface-temperature-recording instruments while the cement is hardening behind the casing. Cement in the process of hardening generates and emits heat, and this fact provides the basis for the geothermal method of determining the position of the cement jacket behind the casing. In making a subsurface-temperate survey of a borehole the temperature- recording instrument is lowered in the hole on a wire line. Borehole temperatures increase uniformly with depth until the instrument is opposite the top of the cement, where, owing to the heat generated and emitted by the cement, a pronounced increase in the temperature is registered. The abrupt break in the temperature gradient indicates the top of the cement.

Advances in oil-well cementing practices have paced advancing drilling technique mainly through cooperative thought and effort of the trained personnel of service organizations specializing in well-cementing work, oil-company engineers, and manufacturers of oil-well cements. To them great credit is due for making it possible to cement wells 10,000 or more feet deep with little more thought and effort than was required a few years ago to cement casing in boreholes only half as deep.

## CHEMICAL METHOD FOR REMOVING MUD SHEATHS IN WELLS

A relatively recent development in well-completion practice is addition of a small amount of pulverized limestone to the circulating mud fluids during drilling through the productive formation so that the resultant mud sheaths formed on the face of the sand will be susceptible to disintegration by acid.[55] When it is desired to expose the faces of the oil sands, 15 percent hydrochloric acid is introduced into the wells, where it dissolves the limestone in the mud sheaths, causing them to disintegrate and expose the oil-bearing sands to the wells. The method has been used extensively in California and in Gulf Coast fields, and recently operators in Wyoming have used the process with remarkable results. According to Hazlett,[56] wells in the Lance Creek field, Wyo., where limestone was added to the drilling fluids and the wells were acidized, were brought into completion and full potential in 3 to 8 hours as compared with 12 to 72 hours and longer where conventional methods of completion were used. Furthermore, Hazlett reports, the rates of production in all wells in which the process was used exceeded those in adjacent areas where the wells were completed and brought in without acid.

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[55] Miller, H. C., and Shea, G. B., Chemical Method for Removing Mud Sheaths in Oil Wells: Bureau of Mines, Rept. of Investigations 3249, 1934, 19 pp.

[56] Hazlett, R. L., Limed Mud Meets with Remarkable Success in Drilling-In Large Lance Creek Producers: Inland Oil Index, Casper, Wyo., May 26, 1939, p. 1.

Mud sheaths in oil wells also are being removed from the faces of producing sands by permeating the deposited sheaths with solutions of soda ash and caustic or strong caustic compounds and then adding acid to the wells to attack the alkaline solutions and disintegrate the mud sheaths.

Not only are mud sheaths formed during drilling or redrilling operations removed from wells by acid, but waxy-asphaltic residues from crude oils and carbonate scale deposited from well waters on the faces of producing sand, particularly in California, now are being removed successfully by chemical methods.[57] Scale deposited in oil wells is largely calcium carbonate, which dissolves readily in inorganic acids, and liquefaction of waxy deposits is accomplished by solvent action or by application of heat-generating caustic

### DEVELOPMENTS IN GRAVEL PACKING OF WELLS

Drastic curtailment of oil-production rates of wells and consequent reduction of current revenue have increased the necessity for producers of oil to utilize every means available to reduce operating costs. As sand produced with oil is one of the major causes of wear and "down time" on pumps, tubing, wellhead fittings, and other equipment, any mitigation of the quantity of sand produced with oil at its source materially increases the life of the equipment and reduces production costs. In many fields the sands of the producing formation are so fine that they cannot be prevented from entering the wells in damaging quantities by the screens and perforated liners ordinarily employed. In these fields gravel packing has proved a practical and simple method of holding back the sand.

Gravel packing of an oil well consists essentially of placing small gravel in an enlarged annular space around the screen or perforated liner opposite the oil-producing zone. The gravel, ordinarily $\frac{1}{10}$ to $\frac{1}{8}$ inch in diameter, is mixed with a viscous oil[58] or with a mixture of bentonite, clay, and water[59] to form a mobile mixture. At some wells the gravel-fluid mixture is pumped through tubing (wash pipe) to the bottom of the well, or if the formation pressures are low, the mixture is poured into the wash pipe; however, the most successful method is to pump batches of the mixture into the annular space between the well casing and tubing and wash each batch down the hole by reversed circulation.

From about January 1, 1937, to midyear 1938, over 65 wells with producing zones ranging from 25 to 666 feet in thickness and at depths of 1,100 to 6,700 feet were completed with gravel-packed liners in California at a cost of $1,050 to $4,650 per well.[60] The additional cost of completing wells by gravel packing is not a materially important factor, as the cost usually is more than offset by the reduction in time required to bring in a gravel-packed well, by reduction in pump wear which commonly is considered to be proportional to the quantity of sand produced, and by increased revenues resulting from higher and more sustained oil-production rates in gravel-packed wells than in those completed in the conventional way.

### COST OF DRILLING

So many different factors affect the drilling of wells for oil and gas that costs in one area may differ widely from those in other parts of the country. In any particular area, however, the depth of the well usually is the predominating factor in determining its cost of drilling, and the deeper the hole usually the greater the expense. The diameter of the borehole, the formations penetrated, number of strings of casing required, and proximity of sources of supply are but a few of the many factors that affect the cost of drilling and equipping wells.

Table 10 gives the estimated cost of drilling wells in various districts of the United States, and table 11 shows the wide range of drilling costs for different depths in a number of fields in California. These data show that the cost of drilling wells for oil and gas in the United States varies widely and indicate

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[57] Morris, M. W., Chemical Clean-Out of Oil Wells in California: Am. Petrol. Inst., Drilling and Production Practice, 1937, p. 220.

[58] Coberly, C. J., and Wagner, E. M., Some Considerations in the Selection and Installation of Gravel Pack for Oil Wells: Am. Inst. Min. and Met. Engr., Tech. Publication 960, Petroleum Technology, August 1938, pp. 1–20.

[59] Clark, W. A., A Résumé of the Application of Gravel Packing to Oil Wells in California: Am. Inst. Min. and Met. Engr., Tech. Publication 1079, Petroleum Technology, August 1939, pp. 1–8.

[60] Clark, W. A., Work cited in footnote 59, p. 4.

that factors other than depth, such as the hardness of the formation penetrated, number of strings of casing required and cost of equipment[61] equally affect drilling costs in some areas.

TABLE 10.—*Estimated cost of drilling wells in the United States in 1939*[1]

| State | Usual depth range (feet) | Average depth of wells to be drilled in 1939 (feet) | Cost of wells | |
|---|---|---|---|---|
| | | | Range | Average |
| Arkansas: | | | | |
| Shallow | 1,400- 2,400 | 2,500 | $8,000-$15,000 | $12,000 |
| Deep | 5,500- 8,000 | 6,900 | 50,000- 90,000 | 55,000 |
| California | 1,200-13,000 | 5,595 | 12,000-250,000 | 60,000 |
| Colorado | 3,000- 7,000 | 3,200 | 20,000- 50,000 | 35,000 |
| Illinois | 1,200- 3,400 | 1,893 | 8,000- 23,000 | 16,000 |
| Indiana | 1,000- 3,000 | 1,142 | 4,000- 12,000 | 6,000 |
| Kansas | 1,500 4,400 | 3,277 | 12,000- 35,000 | 26,000 |
| Kentucky | 200- 3,000 | 1,230 | 2,000- 12,000 | 5,000 |
| Louisiana: | | | | |
| North | 1,600- 8,700 | 4,300 | 10,000-115,000 | 45,000 |
| South | 1,500-10,500 | 6,575 | 15,000-100,000 | 60,000 |
| Michigan | 1,200- 4,000 | 2,500 | 6,000- 19,000 | 15,000 |
| Montana | 1,000- 3,000 | 2,250 | 10,000- 35,000 | 20,000 |
| New Mexico | 2,000- 5,000 | 3,800 | 20,000- 50,000 | 37,000 |
| New York | 1,000- 5,000 | 1,363 | 4,000- 20,000 | 8.000 |
| Ohio | 400- 5,000 | 1,780 | 4,000- 20,000 | 10,000 |
| Oklahoma | 500- 9,000 | 2,962 | 4,000-150,000 | 28,000 |
| Pennsylvania | 200- 5,000 | 1,500 | 3,000- 20,000 | 9,000 |
| Texas: | | | | |
| East | 1,000- 6,100 | 3,800 | 4,000- 50,000 | 16,000 |
| North | 300- 4,000 | 2,400 | 2,000- 30,000 | 14,000 |
| South | 1,000- 8,000 | 3,810 | 4,000- 40,000 | 20,000 |
| Gulf Coast | 1,000- 9,000 | 6,550 | 5,000- 75,000 | 45,000 |
| Panhandle | 2,200- 3,500 | 3,052 | 10,000- 22,000 | 16,000 |
| West | 1,500- 6,000 | 3,600 | 10,000- 40,000 | 27,000 |
| West Central | 1,000- 3,000 | 1,900 | 5,000- 20,000 | 10,000 |
| Utah | 3,000- 6,000 | 5,000 | 25,000- 55,000 | 40,000 |
| West Virginia | 1,000- 5,500 | 2,500 | 4,000- 20,000 | 11,000 |
| Wyoming | 1,200- 7,500 | 3,275 | 8,000- 60,000 | 29,000 |
| United States average | 200-13,000 | 3,173 | 2,000-250,000 | 21,600 |

[1] Table compiled from data given by Brad Mills, Oil Weekly, Jan. 30, 1939, p. 72.

TABLE 11.—*Average costs of drilling oil wells in California*

| Field | Average depth to bottoms of productive wells, feet[1] | Average drilling cost[2] |
|---|---|---|
| Mount Poso | 1,737 | $12,000 |
| West Montebello | 3,208 | 70,000 |
| Wilmington | 3,968 | 50,000 |
| Santa Maria Valley | 4,462 | 40,000 |
| Torrance | 5,290 | 55,000 |
| Coalinga Nose | 6,893 | 100,000 |
| El Segundo | 7.321 | 75,000 |
| Ten Section | 8,219 | 75,000 |
| Canal | 8,259 | 175,000 |
| Kettleman Hills | 10,846 | 135,000 |
| Rio Bravo | 11,469 | 175.000 |
| Greeley | 11,520 | 100,000 |
| Wasco | 13,175 | 250,000 |

[1] Am. Inst. Min. and Met. Eng., Petroleum Development and Technology, 1939, pp. 252–257.
[2] Brad Mills, Oil Weekly, Jan. 30, 1939, p. 72.

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[61] According to Mills (word cited in footnote 63, p. 160), "The service life of drilling equipment directly affects expenditures in every district. The average useful life of most of the heavy equipment is about 4 years, and theoretically a full replacement is effected once during this period. The turnover of equipment receiving the greatest wear is heavier, and such items as chains, drilling lines, bits, drill pipe, and specialty items have no definite service life from a time standpoint."

Although drilling costs in the United States ranging from less than $3 per foot in areas where depths of wells are 2,000 feet or less and cable tools are used to drill the wells to $20 or more per foot in fields where wells are deep, the average cost of drilling and equipping a well is reported to have been $19,100 in 1935,[62] and estimated by Mills[63] from information furnished by oil companies all over the United States, to be $21,600, or $6.80 per foot, in 1939. As the average depth to which wells are being drilled increases each year increasingly higher costs of drilling the average well is a natural expectancy. However, improvements in drilling machinery and equipment and improved drilling technique have tended to retard the rate of increase of cost of drilling constantly deeper wells so that many deep wells today are being drilled at a cost not greatly in excess of that for wells of lesser depth a few years ago.

## TREND OF WELL SPACING

Within recent years, extensive study has been given to the engineering phases of the complicated and as yet unsolved problem of the optimum spacing of wells. Impetus for the study of proper well spacing has been accelerated by the constantly diminishing allowables of producing wells and the advent of deeper drilling with higher development and production costs and lower margins of profit. Formerly—before proration—wells in large numbers were drilled closely together and produced to capacity because the oil was needed to meet current demand. Lease boundaries and offset requirements were about the only limitations placed in well spacing. Although, in the light of present knowledge, such practices may have resulted in the drilling of a large number of "unnecessary" wells, the need for producing as much oil as could be brought to the surface of the ground in as short a time as possible was a paramount consideration on which former producing practices were based. Whether former wide-open-flow methods and close spacing were wasteful in inadequately draining the reservoirs of oil and in leaving large quantities of oil unrecovered in the reservoir sands when the fields reached their economic limit of production is a debatable question. Although the preponderance of opinions expressed at meetings of engineers and published in the technical press seems to be that such practices generally have been inefficient, cognizance should be taken of exceptionally high recoveries from some fields that were produced "wide open" throughout their flowing lives from wells closely spaced and are now virtually depleted of oil and gas.

Today the industry is faced not with the problem of producing all the oil it can in the shortest possible time but of curtailing the current production of the wells already drilled and capable of producing oil so that supply may be balanced with demand and no more oil produced than is necessary to meet current requirements. Most thoughtful students in the industry agree that by restricting production and by the resultant more efficient utilization of reservoir energy, wells can be spaced more widely than before and thereby secure the same or even more effective drainage of oil from reservoirs.

Since the advent of proration engineers have learned the value of conserving reservoir energy. They have found, for example, that by restricting the flow rates of wells—by tubing the wells and applying back pressures at the wellhead—greater volumes of gas are maintained in solution in the oil in the reservoir, and the oil remains more liquid and will flow greater distances through the sands to wells under the same drop in pressure than formerly, when gas was permitted to come out of solution and gas bubbles in the oil increased the resistance of flow to the wells. Increasing the efficiency of recovery of oil from the sands follows in the wake of measures taken to conserve the reservoir gas. Production costs also are reduced because wells flow naturally for a longer time and the installation of expensive pumping equipment and the high cost of its operation are deferred when reservoir gas is conserved in the reservoir sands.

According to Miller and Miller:[64]

"There was a time when a majority of operators produced oil with no regard for the volume of gas accompanying it to the surface; but today such practice

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[62] Kiessling, O. E., Rogers, H. O., and others, Technology, Employment, and Output per Man in Petroleum and Natural-Gas Production: W. P. A. National Research Project, in cooperation with the Bureau of Mines, Report E–10, July 1939, p. 199.

[63] Mills, Brad, Greater Well Depths will Increase Drilling Costs in 1939: Oil Weekly, Jan. 30, 1939, p. 70.

[64] Miller, F. G., and Miller, H. C., Résumé of Problems Relating to Edgewater Encroachment in Oil Sands: Bureau of Mines, Rept. of Investigations 3392, 1938, p. 2.

is roundly condemned by almost every producer, and no longer is there any doubt as to the benefits accruing in increased recovery of oil from reservoir sands through systematic control of gas-oil ratios. The preponderance of evidence, both laboratory and field, showing the benefits to be derived from efficient use of the energy inherent in the gas under pressure in reservoir sands has convinced even the skeptic that the production of oil with high gas-oil ratios leads not only to wastage of gas but results in reduced recovery of oil from the reservoir. As a result of the study and thought given to the value of the gas associated with oil under pressure in reservoir formations and to methods by which the gas can be used most efficiently to move oil through the sands to wells, oil-recovery efficiencies have increased and operators today are recovering much oil that would have been left unrecovered under former, less-scientific production practices.

"Gas under pressure, however, is not the only source of energy available in many reservoirs to drive oil through the pore spaces in the sands or rocks to the wells. In many of the petroleum reservoirs in the United States, oil is underlain by water under pressure and in volume sufficient to displace all the recoverable oil. In such fields, the energy required to produce the oil is not derived from the gas in solution or occluded in the oil and in the gas-filled part of the reservoir but is due to the head of water in the extraneous part of the reservoir. The entrance of meteoric water at the outcrop tends to maintain the pressure head in the oil-producing sands. Where the water contains considerable gas in solution, the water that moves into the oil-filled part of the reservoir receives its energy from the expansion of the fluids behind the oil. There the force of the natural water drive can be used to best advantage in propelling oil to wells by producing the fields at a sufficiently low rate that the water furnishes all of the energy and completely replaces the oil in the pore spaces of the sand. If such control was made effective as soon as the first well in a field was completed, reservoir pressures could be maintained more nearly at their original intensity, no gas would be liberated from solution in the oil and thereby increase the viscosity of the oil and reduce the 'effective permeability' of the sand, gas-oil ratios of production would be the same as formation gas-oil ratios, wells would flow naturally throughout their producing life, and oil-recovery efficiencies would be high."

Proration restrictions, by balancing output of oil against reservoir pressure changes, have tended in a large measure to equalize withdrawal of oil and input of water. Conservation demands that the production of oil in all pools should be controlled, or curtailed enough, to prevent the loss or wastage of the reservoir energy inherent in the oil, gas, and water. This will minimize underground waste of oil and lead to recovery of the maximum quantity of oil from the sands.

Proper well spacing—field development in accordance with sound engineering practices—assures maximum yield of oil from a pool. It is recognized that a spacing best suited for one pool may not be ideal for another or even for different parts of the same pool if its areal extent is widespread. Nevertheless, in every pool or in parts of pools there is an optimum well spacing and optimum rate of oil withdrawal by means of which the maximum amount of recoverable oil can be produced at the minimum of cost. Under such conditions there will be no expenditure of money for drilling unnecessary wells or unneeded duplication of development and operating costs.

In general, the trend in well spacing is to space wells farther apart than formerly. Obviously there is a limit to how far wells should be spaced, but spacing the wells farther apart than has been customary in many fields in the past seems to have so many advantages that progressive operators hesitate to recommend close spacing where wider spacing is possible.

Most oil-producing States have incorporated well-spacing rules in their regulatory statutes, and the decisions[65] upholding the validity of Texas legislation regarding well spacing are evidence that the courts are becoming cognizant of the physical and economic waste resulting from too close spacing of wells.

Despite the progress that has been made in preventing drainage from one property to another through maintenance of proper pressure gradients and other devised means of controlling production the "one largest obstacle," as Knowlton[66] states, "that is keeping the industry from attaining a stable and intelligent program of development is the law in most of our oil-producing States. These

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[65] Oil Keekly, *Arkansas Fuel Oil Company* v. *Reprimo Oil Company:* Feb. 10, 1936, p. 8.
[63] Knowlton, D. R., Future of Well Spacing: Oil Weekly, May 17, 1937, p. 51.

statutes being fundamentally based on the 'Law of Capture' are essentially contrary to conservation and economic stability." In other words, the present oil and gas statutes do not conform with the progress made in the science of production, as they preclude not only the most efficient use of reservoir energy, thus reducing ultimate recovery, but promote rapid development of an oil field and excessive and unnecessary drilling.

Inasmuch as the forces tending to drive oil to wells in a given pool are limited, and good business demands using the available energy to the maximum benefit in physical and economic recovery of oil, too many wells in a pool can result in noncommercial rates of production. Engineers have determined that the optimum daily production rate for the East Texas field, for example, is about 400,000 barrels of oil a day. At the end of 1938 there were 25,588 producing oil wells in the field, an average of 1 well to 5.2 acres. Dividing the optimum production rate by the number of wells gives each well an average daily production of slightly less than 16 barrels of oil. Careful engineering estimates made by the best qualified persons indicate that equally efficient recovery at the current rate of production from the field would result if only half as many wells had been drilled. Thus, because approximately 12,000 unnecessary wells were drilled, wells are spaced abnormally close in the East Texas field, and allowable daily production is approximately half of what it would be if the well-spacing pattern had been 1 well to 10 acres and the field allowable remained unchanged.

If, then, under proration, wells are closely spaced and more are drilled than are needed to drain a given pool effectively at a specific rate of production, it is obvious that those drilled in excess of the number required to drain the reservoir adequately are unnecessary. Under proration the drilling of unnecessary wells has a direct effect on the pocketbooks of all operators, royalty owners, and the consuming public that ultimately pays for the drilling of these unnecessary wells in the form of higher prices for petroleum products.

### HIGH COST OF DRILLING "UNNECESSARY" WELLS

In almost every oil-producing area where production is on a highly competitive basis, many more wells are drilled than is necessary for economic ultimate recovery of the oil from the underlying reservoir.

Probably 4,000 to 5,000 unnecessary wells[67] are drilled each year in the United States, at a drilling cost of $80,000,000 to $100,000,000.[68] This annual cost of unnecessary drilling is equivalent to a self-imposed gross production tax of about 10 cents per barrel of oil produced.

The cost of unnecessary drilling in proved fields in the United States has been subject to extensive studies by engineers and various committees of engineers and others. All agree that in many fields the industry is operating under an unnecessarily heavy load resulting from conditions of competitive development traceable directly to interpretations of the rule of capture that permit an operator legally to claim posession of all oil and gas that he can bring to the surface of the ground through wells drilled on his property and influence him, therefore, to drill more wells than are necessary to recover the producible oil from beneath his land.

One of the most thorough studies of the evils attending unnecessary drilling in proved fields and the remedy was made in 1936 by the subcommittee of nine of the committee on balance of supply with demand of the Independent Petroleum Association of America. The following statements regarding drilling in the East Texas and Oklahoma City fields are from the subcommittee's report.[69]

"The statement has often been made by reputable engineers that one well to each 20 acres in the East Texas field, properly spaced, and with production scientifically allocated, would result in the recovery of approximately as much oil as would take place under 10-acre, 5-acre, 2-acre, or even 1-acre spacing. It has often been stated that the total number of unnecessary wells in the East Texas

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[67] A generally accepted definition for an unnecessary well is one that will fail to increase ultimate recovery of oil from the pool by an amount sufficient to return the cost of investment, plus the cost of operation and royalties and a reasonable profit. "Wildcat" or exploratory wells do not come under the classification of unnecessary wells, whether or not such exploration is productive of oil. It is generally believed that the chances of discovering new sources of oil should not be restricted, as the margin of reserves seldom is great enough to justify curtailment of exploratory efforts.

[68] Ely, Northcutt, Legal Restraints on Drilling and Production: Reprint of address delivery before Section of Mineral Law of the American Bar Association, Kansas City, Mo., Sept. 28, 1937, p. 47.

[69] Independent Petroleum Association of America release. Dec. 1. 1936.

field may conservatively be fixed at 12,500. * * * If we assume that the average cost of drilling a well in the East Texas field over a 3-year period is $13,000 * * * then the total unnecessary expense merely for the drilling of the 12,500 unnecessary wells is in round figures $162,000,000.[70] It appears that the average allowable per day in the East Texas field for several years has been about 435,000 barrels, which in round numbers would be 159,000,000 barrels per year. The posted price has been approximately $1.00 per barrel. It is clear, therefore, that, if the unnecessary drilling of some 12,500 wells had not taken place, the operators would have saved the cost of such wells, or approximately $162,000,000. The saving of that sum would be equivalent, as far as income to operators is concerned, to receiving more than $2.00 a barrel instead of $1.00 per barrel actually received during the entire year of 1935. The saving would be considerably larger if taxes, operating costs, and other expenses incident to the drilling of unnecessary wells should be considered.

"Conditions in the Oklahoma City pool offer further illustration. Reputable engineers have stated that one well in the Wilcox horizon will efficiently drain at least 10 acres under proper proration. Assuming as correct the estimate frequently given that the area of the productive Wilcox horizon is 3,600 acres, then 360 wells would have been ample to recover the oil, instead of 677 wells which were actually drilled and are producing today. The average cost of such wells has been given as $100,000 each. It follows, under such facts as assumed, that 317 unnecessary wells were drilled at a total cost of $31,700,000. If such unnecessary cost had been saved, the saving would have been equivalent to an increase in price of 75 cents a barrel for the production of the Wilcox zone for an entire year."

Many other fields also have been "overdeveloped" by the drilling of many wells which, according to advanced thought, were not necessary for maximum economic ultimate recovery of the oil. Spindletop, Powell, Seminole, Long Beach, Huntington Beach, Santa Fe Springs, and Wilmington are but a few of many fields that can be cited as having been developed by the drilling of more than the number of wells now considered essential to produce the recoverable oil from the sands economically.

As has been stated aptly by Phillips:[71]

"Until recent years, wells were spaced arbitrarily, with little or no regard to technical considerations which control effective drainage of producing sands. The economics of this problem have received little real consideration. Today we know that wider well spacing than has been the custom of the past, when coupled with conservation of reservoir pressure, results in a more thorough drainage of the producing horizon than does close spacing and unscientific producing methods. At any rate, what argument is there in favor of close well spacing if it causes the venture to be unprofitable, when the wider spacing would permit the venture to be profitable?

"Fewer wells per unit of area are the key to this economic puzzle. Take the State of Texas, for instance, where over half of this Nation's known oil reserves are located. Five years ago, the average daily production of all wells subject to proration in that State was 40.8 barrels. Last year, this daily average production for proratable wells had declined to 23.7 barrels. It has been forecast that, under a continuation of present drilling policy, 4 years from now the average daily production from proratable wells will be down to approximately 14 barrels. It is obvious to anyone who considers this question, therefore, that additional drilling of wells simply causes further subdivision of the available market demand among a greater number of wells. At the same time it increases investment per barrel and producing cost per barrel. Irrespective of all other considerations, including technical and scientific ones, bare economics demand that we drill fewer wells. Obviously, the practical way to drill fewer wells is to increase the number of acres to be drained by new wells, and accompany this wider spacing with efficient reservoir control."

Although the efficient use of reservoir energy is in effect a substitute for the drilling of unnecessary wells it is unfortunate that legislation in certain States definitely invites operators to drill additional wells to increase their allowable production. As long as conservation statutes contain provisions that base allowables largely on the potential production capacities of wells, on the straight-well

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[70] Authors' note: According to Frank Phillips, chairman, Phillips Petroleum Co., in an article, entitled "Streamlined Science Needs Horse-Sense Economics," published originally in Mines Magazine, June 1939, pp. 251–256, and later in Oil Weekly, Aug. 14, 1939, pp. 13–20 the cost of drilling unnecessary wells to 1939, in the East Texas field, is estimated at over $200,000,000.

[71] Phillips, Frank, Work cited in footnote 70.

basis, or on other factors that ignore the quantity of oil in place, proration will be ineffective in its practical and equitable operation. Greater consideration than has been given in most proration regulations should be given to the factor of acreage in order to discourage the drilling of unnecessary wells. Certainly there is no justice in allowing one operator in a field to drill only 1 well on a 10-acre tract when his neighbors are permitted to drill 2, 5, or as many as 10 wells on a similar-size tract, and all wells in the field are permitted to produce the same quantity of oil daily.

In reference to this general subject, Knowlton,[72] general production superintendent, Phillips Petroleum Co., states:

"In most oil States the laws have not digressed sufficiently from the old 'Law of Capture' to eliminate much of the unnecessary and excessive drilling that now exists. Much of the close spacing has not taken place because the operators on the whole believe that the larger number of wells which are drilled in a field the greater will be the ultimate recovery from such field. In a great many instances this excessive and unnecessary drilling has occurred in proven fields where the proration or allocation formula in those areas is founded on a per-well basis or on some combination of factors which gives excessive weight to the well and which gives too small a value to acreage or recoverable reserves. Under the per-well method of allocation, where proration exists, an operator is prohibited from drilling on a larger tract than his neighbor or to a less dense pattern because of the regional drainage that will take place and remove oil from under his tract and be produced by the areas that are more densely drilled.

"There is a vast difference in the principle of close spacing in order to get a high allowable on a per-well basis of proration compared to a close spacing in order to increase the ultimate production from the pool as a whole. This has often been confused, and many of the arguments in favor of close spacing for greater ultimate recovery are in reality a subterfuge to permit the drainage of offset properties. Until laws in the various States have been enacted which will recognize a liberal acreage factor and 'Oil in Place' rather than 'Law of Capture,' a premium will be placed on well potentials and well allowables and conservation and equity will be neglected. The distribution of allowables on a per-well basis results in condensed drilling and withdrawals in certain areas of a pool, thus creating low-pressure areas in the reservoir, which bring about irregular and premature encroachment of water, irregular and premature expansion of the gas cap due to gas coming out of solution from the oil, and the inefficient use of gas energy within the reservoir. Until laws are passed providing operators the rights of allocation and proration plans which will eliminate this spotted condition of drilling, little conservation of oil and gas within the reservoir can be realized It is not absolutely necessary to insist on uniform spacing within any pool, and many plans have been defeated because of the attempt to do this. However, it is necessary to allocate the allowable oil on an acreage basis in order to reach the ultimate aim of keeping the reservoir in equilibrium."

According to K. C. Sclater, editor, The Petroleum Engineer:[73] "inclusion of acreage for determining well allowables in the East Texas field was suggested in a recent court ruling. A group of operators in that field has shown violent opposition to the consideration of acreage in any form in allocation formulas with the plea that it will work a hardship on many of the small operators. It is hard to reconcile the viewpoints of opponents to the court's suggestion on the grounds that it will be a hardship on the small operators."

A consideration of acreage, according to Sclater, seems to be the only way in which an irrational program of close drilling with its ultimate detriment to the field can be avoided.

Of course, inclusion of the acreage factor in an allocation formula may mean that a well with a 20-acre spacing will be allowed to produce twice as much oil as a well with a 10-acre spacing, or four times as much as the well on a 5-acre spacing, but basically such a distribution of allowable is more equitable alike to the small and large producer than allocation measures ignoring acreage.

## WELL SPACING AND ESTIMATED OIL RECOVERIES IN 17 FIELDS OF THE UNITED STATES

The well spacings and estimated ultimate recoveries in a number of oil fields are given in table 12. Because many of the data upon which this table is based were taken from published reports and from other sources, and because

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[72] Knowlton, D. R., Future of Well Spacing: Oil Weekly, May 17, 1937, p. 52.

[73] Sclater, K. C., The Course of Oil: Petrol. Eng., July 1939, p. 8.

various authorities have slightly different opinions as to the number of producing wells, productive acreage, thickness of the producing formations, and quantity of oil that will be produced ultimately from the fields, exact figures cannot be given either for the well spacing or the oil recoveries per acre-foot. In the East Texas field, for example, there seems to be a difference of opinion regarding the number of productive acres in the field, the thickness of the producing formation, and the number of wells, although the quantity of oil that will be produced ultimately (4,000,000,000 barrels) is quite generally agreed upon. Some engineers report 135,000 productive acres in the East Texas field; others 133,500 acres. Some estimate the thickness of the sand to average 35 feet; a few believe 40 feet is more nearly correct; and still others split the difference and consider the average thickness of the producing sand in the East Texas field to be 37½ feet. Accordingly, the well spacing in the East Texas field may be 5.0 or 5.2 acres per well, and the estimated ultimate oil recoveries per acre-foot 655, 740, 800, or 860 barrels, depending on the figures used for estimated ultimate field recovery, productive acreage in the field, and thickness of the producing sand.

As opinions of conditions in many of the other fields listed in table 12 also differ, single figures usually cannot be given for the well spacing and ultimate oil recovery per acre-foot. Therefore, as for the East Texas field, series of estimates are given to indicate, in some measure at least, probable recoveries of oil per acre-foot for not greatly divergent well spacings in a number of fields.

TABLE 12.—*Well spacing, oil recovery relations in a number of fields of the United States*[1]

| Field | Well spacing, acres per well | Estimated ultimate oil recoveries, bbl. per acre-foot |
|---|---|---|
| East Texas, Tex | 5.0– 5.2 | 655–740–800–860 |
| Thompson, Tex | 16.6–20.8 | 400–510–613 |
| Conroe, Tex | 18.5–20.1 | 300–495–520–675 |
| Van, Tex | 8.0 | 413–625–700 |
| Yates, Tex | 36.2–38.0 | 175–300–338 |
| Hendricks, Tex | 17.5–19.1 | 275–300–325 |
| Mexia, Tex | 6.1 | 600–625 |
| Wortham, Tex | 2.4 | 1,175–1,200 |
| Currie, Tex | 5.8 | 725–750 |
| Richland, Tex | 2.5 | 1,300–1,350 |
| Powell, Tex | 3.5 | 900–925 |
| Hogback, N. Mex | 23.0 | 1,650 |
| Hobbs, N. Mex | 38.0–39.5 | 150–164–200 |
| Salt Creek, First Wall Creek, Wyo | 13.7 | 108–145 |
| Rock Creek, Wyo | 18.3–20.0 | 125–175–177 |
| Iles, Colo | 15.4–17.6 | 950–970–1,250 |
| Kettleman Hills, Calif.[2] | 40 | 187 |

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[1] The assistance given by H. B. Hill, supervising engineer, Bureau of Mines, Dallas, Tex., in furnishing some of the data given in the table is gratefully acknowledged.

[2] Patterson, Robert C., Supervisor, Geol. Survey, Los Angeles, Calif. See Petrol. World, February 1939, p. 23.

The data given in table 12 show that factors other than well spacing enter into the problem of oil recoveries. Some of the fields listed in the table were operated throughout their producing lives without any restriction of production rates; others have been under proration throughout or almost throughout their lives. For the latter, there is considerable question as to the accuracy of the recovery figures because the data on fields that have been operated from the beginning of their producing lives in a manner now considered efficient are limited and need to be augmented by additional data extending over comparatively long periods to enable engineers to make reasonably accurate estimates of the probable ultimate recoveries of oil.

The economics of the well-spacing problem has received little consideration in the past. As long as wells were allowed to produce unrestricted and there was a demand for all the oil produced at a price yielding a profit commensurate with the risk involved and permitting the wells to pay out in a reasonable time the economics of the well-spacing problem was of secondary importance. Today the fact is fairly well established that wider well spacing than has been customary in the past and scientific producing methods will result in equally as thorough drainage of oil from reservoirs as closer well spacing and less scientific methods of production, although the time required to extract the oil may be lengthened. Nevertheless, aside from all engineering considerations, what logic is there in drilling x wells when $\frac{x}{2}$ wells drilled at half the cost and producing at twice the rate will effectively drain the reservoir and furnish sufficient oil for current needs? If, under proration, the drilling of additional wells does not increase the total quantity of oil produced in a field, it is obvious that in fields already developed with enough wells to produce the recoverable oil within a reasonable time every additional well drilled is unnecessary and merely increases investment and producing cost per barrel and the price that the ultimate consumer has to pay for his oil.

### CUTLER'S RULE OF WELL SPACING

In 1924, when oil wells commonly were produced "wide open" and permitted to produce currently all the oil that could be brought to the surface of the ground, Willard W. Cutler, Jr., then a petroleum engineer of the Bureau of Mines, published a bulletin[74] in which he gave a tentative rule of well spacing that in the interim has generally become known as Cutler's rule of well spacing. The rule, as given on page 89 of Cutler's bulletin, states:

"The ultimate productions for wells of equal size in the same pool, where there is interference (shown by a difference in the production-decline curves for different spacing), seem approximately to vary directly as the square roots of the areas drained by the wells."

In other words, the rule infers that halving the distance between wells results in halving the ultimate productions for wells of equal size and on doubling the recovery of oil from the pool.

Because Cutler's rule has been misquoted frequently and often incorrectly interpreted, H. C. Miller and R. V. Higgins, senior and assistant petroleum engineers, respectively, of the Bureau of Mines, have restudied Cutler's published rule and the data on which it was formulated to determine whether increased understanding of oil-reservoir mechanics and technical progress in development and producing practices during the last 15 years might not have nullified or modified some of the earlier conclusions of Cutler, based upon the data then available to him.

The following excerpts are from the summary and conclusion of their report:[75]

"The rule (Cutler's) does not infer, * * *, as many persons seem to believe, that twice as much oil will be recovered ultimately from a pool developed to a certain spacing pattern as would have been recovered if the number of acres allotted to each well had been twice as great. Rigorously interpreted, the rule implies that a pool developed to a 5-acre-per-well spacing pattern, for example, will produce ultimately only about 41 percent ($\sqrt{2}=1.41$) more oil, and not 100 percent more, than would have been recovered from the same pool under similar conditions of production if the wells had been spaced 1 well to 10 acres.

"To obtain twice the recovery of oil in a pool in which the wells are spaced 1 well to 10 acres would require, according to Cutler's rule, the drilling of 1 well to every 2½ acres. In other words, 64 wells will be required, according to Cutler's rule, in a 160-acre pool to recover twice as much oil as would have been produced ultimately if there had been only 16 wells to the 160 acres—a spacing of 1 well to 10 acres. Obviously, even in those pools where Cutler's rule seems approximately to accord with facts, the spacing of wells within reasonable spacing limits largely is an economic problem, and depends mainly upon the price obtained for the oil and the cost of drilling the wells and producing the oil.

"The relation between well spacing and oil recovery in pools is receiving serious consideration by Bureau of Mines engineers, and for a number of years they have been collecting oil-production and well-spacing data on wells and pools throughout the United States. Although conclusive statements regarding the relation between well spacing and oil recovery cannot be made at this time without some risk of criticism of the accuracy of the data on which they are based, the information at hand apparently indicates that for old fields, which during their flowing lives were produced 'wide-open,' and to a lesser extent for newer

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[74] Cutler, Willard W., Jr., Estimation of Underground Oil Reserves by Oil-Well Production Curves: Bureau of Mines Bull. 228, 1924, 114 pp.

[75] Miller, H. C., and Higgins, R. V., Review of Cutler's Rule of Well Spacing. Bureau of Mines Rept. of Investigations 3479, November 1939, 23 pp.

fields operated from the start under production control, additional oil might have been recovered ultimately by the drilling of additional wells. * * * Whereas the data indicate that for those fields where the wells flowed wide open the relation between well spacing and oil recovery per acre over a narrow range of spacings is approximately in accordance with Cutler's rule, they seem to show for fields operated at restricted-flow rates in accordance with accepted good production practice that if additional wells are drilled in those fields the increase in recovery per acre due to closer spacing of the wells would be only fractionally as great as it would be if oil recovery were proportional to the reciprocal of the square root of the acres per well as stated by Cutler in his rule in 1924. In other words, for many fields—especially those with deep-lying, high-pressure sands, operated under modern methods—the line on logarithmic paper showing the relation between oil recovery per acre and spacings will have a lesser slope than that based on Cutler's rule. It seems, therefore, that in the United States the optimum spacing of wells in the majority of fields is even more a problem of economics than it is either in those fields where wells seem to have definite limiting radii of drainage or in those where the wells still are permitted to flow to capacity with little consideration to efficient use of reservoir energy.

"Thus, although a study of oil recoveries in many pools which now may be considered in the minority indicates that Cutler's rule approximately defines the relation between recovery and well spacing (over a narrow range of spacings), production data on gas-drive and natural water-drive fields, where the oil-bearing formations are under high pressures and with more than enough reservoir energy to move all the recoverable oil through the sands to the wells, have not yet accumulated in sufficient quantity to permit determining definitely whether a similar relation between recovery and spacing exists in those fields. Furthermore, indicative as the available information seems to be, production data substantiating the advanced thought that oil recoveries are increased when oil pools are produced at restricted rates, with low gas-oil ratios and minimum drops in reservoir pressures per unit quantity of oil produced so as to get the maximum benefit in greater oil recovery from the inherent reservoir energy, are as yet incomplete. Field data indicating the comparative extent to which former methods of operating wells wide open and spacing them closely led to greater waste of oil in the undergrgound reservoirs than present methods of production also are not yet available in sufficient quantity to declare confidently the advantages of wide spacing and restricted flow on increased oil recovery in so-called efficiently operated pools. Therefore, until the limited amount of field data on those fields that have been operated from the start of their producing lives in a manner now considered efficient has been augmented by considerable additional data extending over comparatively long periods of time, so as to enable engineers to make reasonably accurate estimates of the probable ultimate recovery of oil, any statements relating to the applicability of Cutler's rule to those fields, or to the extent to which recoveries may deviate from the rule, cannot be founded on actual field performance and may be considerably in error. Therefore, for the present and until it no longer is necessary to premise estimates of ultimate recoveries from pools upon uncertain, long-range forecasts, and until more definite statements can be made than are possible at this time regarding the relation between oil recovery and well spacing in pools operated from the start of their producing lives in a manner now considered efficient, Cutler's rule should be considered merely as defining approximately the relation between ultimate productions and well spacings in certain fields, and then over only limited ranges of spacings. Any assumption, however, that the rule applies in general to all pools regardless of type and methods of producing them cannot be accepted as true, because such a supposition fails to take into consideration the dissimilarity and complexity of oil-producing reservoirs and the fact that the behavior of deep-seated, high-pressure reservoirs undergoing depletion differs widely from that observed by Cutler in those shallower, lower-pressure pools on whose performances the tentative rule originally was based."

### PROBLEM OF THE SMALL TRACT UNDER SPACING REGULATIONS

The difficulties in maintaining the specific spacing pattern provided for in the spacing rules for a particular field begin with the small tracts that do not contain enough acreage to be developed by one well under the spacing rules.

Speaking before the mineral law section of the Texas Bar Association on the problem of the small tract under spacing regulations, Dr. A. W. Walker, Jr., professor of oil and gas law at the University of Texas and president of the Texas Petroleum Council, stated in part:[76]

"In order to prevent confiscation of the oil of either the small-tract owner, or of the other landowners over the common reservoir, three different plans have been adopted. The first plan is the one used in the East Texas oil field and in other fields in the State developed prior to the discovery of the East Texas field. It involves nothing more than an application of rule 37 in substantially the same form in which it was originally promulgated in 1919. (Rule 37 dates from an order of the Railroad Commission of Texas made July 26, 1919, re-adopted November 16, 1919. The rule provides that no well for oil and gas shall be drilled nearer than 300 feet to any completed or drilling well on the same tract, or nearer than 150 feet to any property line. It is provided further that the Commission may grant exceptions permitting drilling within shorter distances where necessary to prevent waste or prevent confiscation of property.) This rule was devised long before proration or marginal well allowances were adopted, and it seems to have worked fairly satisfactory under open-flow conditions prevailing prior to the development of these new complications which it was not designed to meet.[77]

"The East Texas field was discovered in 1930 prior to the adoption of proration in this State. Hence it was only natural that rule 37, then 11 years old, and with a long record of successful operation, should have been automatically applied to that field. No one then foresaw the difficulties that would arise in the application of that rule to a large oil field where small tracts are numerous and under the complications that were to arise subsequently when proration and marginal well statutes were enacted.

"Under this plan the owner of every small tract which has been segregated prior to the adoption of rule 37, or, as more recently qualified,[78] even if the segregation occurred after the adoption of the rule so long as it was before discovery of oil within the vicinity of the tract, is entitled to the first well as a matter of right. No reduction in the allowable of this well is made because of the smallness of the tract, even though the tract may be only one-hundredth the size of the tract provided for in the spacing rule. Any well obtained after the first well on the small tract must be obtained on the basis that it is necessary to enable the owner to produce the recoverable oil beneath his tract, and in making this determination the well density on his tract is contrasted with the average well density upon neighboring tracts.[79] Owners of large tracts may also obtain exceptions to the spacing rule in order to equalize the well density of their tracts with the well density on neighboring lands.

"In any field where small tracts are numerous, as was the case in the East Texas field, it has been demonstrated that this method of dealing with the small-tract problem inevitably leads to a virtual abrogation of the spacing pattern adopted for the field and its spacing rule, and to the drilling of numerous unnecessary wells as defined herein. The granting of one exception immediately makes it necessary to grant other exceptions in order to prevent confiscation. Statistics reveal that this is true.

"Despite the 10-acre spacing rule, 25,000 wells have already been drilled in the East Texas oil field, representing a density of one well to a little over five acres. The great majority of these wells were drilled as exceptions to the spacing rule. It is estimated that approximately 8,000 more wells will be drilled as exceptions to the rule,[80] which will reduce the average well density down to one well to four acres. If one well to every 10 acres, as provided in the spacing rule, would have permitted the drilling of all wells needed to efficiently produce the oil from this field, it is apparent that approximately 12,000 unnecessary wells have already

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[76] The complete text of Professor Walker's paper is printed in the August 11, 1938, issue of Oil and Gas Journal, starting on p. 41.

[77] One of the reasons for its more successful operations under open-flow conditions is that the area efficiently drained by a well permitted to produce at full capacity is apparently much smaller than that of a restricted-flow well where full advantage is taken of the reservoir energy in producing the oil. Furthermore, rule 37, in its original form, provided for a well location of only a little in excess of two acres. Hence, very few tracts were denied a well under the rule. There were, however, a few cases in which the spacing rule was assailed prior to proration. See *Oxford Oil Co.* v. *Atlantic Oil & Producing Co.*, 16 Fed. (2d) 639, aff'd, 22 Fed. (2d) 597, cert. denied, 227 U. S. 585, 48 Sup. Ct. 433, 72 L. Ed. 1000 (1927); *Humble Oil & Refining Co.* v. *Strauss*, 243, S. W. 528; *Railroad Commission* v. *Bass*, 10 S. W. (2d) 586; *State* v. *Jarmon*, 25 S. W. (2d) 936.

[78] *Shell Petroleum Corp.* v. *Railroad Commission*, 116 S. W. (2d) 220.

[79] *Smith County Oil & Gas Co.* v. *Humble Oil & Refining Co.*, 112 S. W. (2d) 220.

[80] *Oil and gas Journal*, Apr. 14, 1938, p. 111.

been drilled and that before drilling ceases the total unnecessary wells will be approximately 20,000.

"If it is desirable to maintain the drilling pattern contemplated in a spacing rule, as must be assumed from the very fact that a spacing rule has been adopted, it is obvious that this plan of dealing with the small-tract problem is a complete failure. It encourages and, in fact, makes necessary the drilling of numerous unnecessary wells, and brings about all of the evils that the spacing rules were intended to prevent. It is harmful to the operators in the field in question because they are compelled to drill unnecessary wells in order to prevent their oil from being confiscated by operators who have obtained exceptions to the spacing rules. It is injurious to operators and landowners in other sections of the State because these unnecessary wells consume a portion of the total State allowable which their wells might otherwise have obtained, and thus results in their allowables being reduced. Furthermore, these unnecessary wells represent, no doubt, in part a diversion of drilling expenditures that should have been made in other portions of the State where the landowners are sorely in need of additional wells for the proper development of their land.

"From an administrative standpoint the plan used in the East Texas field has not been a success. It has placed an exceedingly complex and difficult administrative burden upon the railroad commission, as is attested by the thousands of applications for exceptions which that administrative agency has been compelled to pass upon. And the courts have been forced to bear a considerable part of this burden. The dockets of the district courts of Travis County have been crowded with these cases for years, and many of them have found their way into the appellate courts. And despite the granting of these thousands of exceptions, and the trial of these numerous cases, the law as to many procedural and administrative questions cannot yet be regarded as settled. The attorney fees that have been paid by applicants and protestants must have run into millions of dollars. As an administrative regulation it has been complex, burdensome, and costly to the administrative body, to the courts, and to the operators * * *.

"The marginal-well statute, however, has introduced an artificial factor into the small-tract problem that requires consideration. Our statutes[81] define a marginal well as a pumping well capable of producing certain amounts of oil or less at various specified depths, which, if its production were curtailed below such stated amounts, would be damaged, or result in a loss of the production ultimately recoverable, or cause the premature abandonment of the well. This statute has not been judicially construed. Since flowing wells are frequently found in the same oil field closely associated with pumping wells, the railroad commission has never undertaken to reduce the allowable of a flowing well below that of a pumping well, with the result that a flowing well is also regarded as entitled to a proration allowable at least equal to the marginal-well allowance of a pumping well of the same depth. Furthermore, pumping wells have always been given their marginal-well allowance despite the fact that the statute obviously contemplates that the allowable of a pumping well may be reduced below its marginal allowance if such curtailment would not result in damage to the well, cause its premature abandonment, or result in a loss of the production ultimately recoverable. Apparently, also, the railroad commission has adopted the view that a well drilled upon a tract smaller than that permitted by the spacing rules is, nevertheless, entitled to the full benefit of the marginal-well statute.

"The net result of the marginal well statute, as now interpreted by the administrative agency, and as applied to the small-tract problem is that any well drilled upon a small tract, regardless of how small it may be, and regardless of whether it is a pumping or a flowing well, is entitled to the full marginal well allowance of a well of its depth.

"In oil fields, such as East Texas where the proration allowable for a well drilled in accordance with the spacing rules is only 2 or 3 barrels per day more than the 20-barrel marginal well allowance for a well in that field, it is obvious that the marginal well statute, so long as it is interpreted and applied as at present, prevents the allowable of a well drilled upon a very small tract from being reduced to such an amount as would entitle it merely to produce the recoverable oil in place beneath the small tract and no more. The result is that the oil of neighboring landowners will be confiscated by the well on the small tract unless they too are permitted to drill wells as exceptions to the spacing rule.

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[81] Art. 6049 (b), Ver. Ann. Tex. Civ. Sts.

"Furthermore, it is obvious that, if enough exceptions are actually granted to the neighboring tracts to allow them to produce the recoverable oil beneath their land, and to avert confiscation by preventing the well on the small tract from recovering more oil than is in place beneath the small tract, then the well on the small tract will necessarily be an unprofitable well in all instances where the amount of oil in place beneath the small tract was not sufficient to repay drilling and operating costs. But, in order to effect this rule, the operators on adjoining tracts would be compelled to drill so many wells that each of their wells would also become unprofitable.

"As a practical matter, the owners of the neighboring lands, as sensible business men, would prefer to have some of their oil confiscated rather than to drill so many wells as to render their operations entirely unprofitable. Hence, it is frequently very profitable to drill a well upon a very small tract of land even though there is not enough oil beneath that land to repay drilling and operating costs. The applicant knows that he will be able to drain enough oil from adjoining properties to render his well profitable, and thus is given an incentive to drill a well under these circumstances.

"A second plan for handling the small-tract problem has been adopted in most, if not all, of the fields discovered since the East Texas field. This plan also contemplates the granting of the first well to the small tract as a matter of right. In order to prevent confiscation of property, however, this plan provides for a reduction in the allowable of the well drilled upon a small tract because of its deficiency in acreage. In this manner it is designed to avoid one of the principal defects in the first plan in that it is hoped that the granting of an exception to the small tract with a reduced allowable will not make it necessary to grant exceptions to neighboring large tracts. The only reasonable standard upon which to reduce the allowable of the well upon the small tract is to reduce it to such an extent as will prevent the well from producing more than the amount of recoverable oil in place beneath the small tract. Only in this manner can the issue of confiscation be avoided.

"This standard will work satisfactorily in the case of a tract only slightly smaller than the area required for a well location under the spacing rules. However, in the case of very small tracts, this standard is not workable where the total amount of oil in place beneath the small tract is insufficient to repay the cost of drilling the well plus operating expenses. The result would be that the owner of the small tract could not afford to drill a well and his oil would be drained away by neighboring operators.

"To obviate this difficulty a compromise standard for the reduction of the allowable of a well drilled on the small tract has been adopted. The usual practice is to allot one-half of the field allowable to well potentials and the other one-half to acreage. The well on the small tract receives its full share of the field-potential allowable based upon its potential. However, in computing its share of the acreage allowable, a reduction is made based upon the ratio of the size of the small tract to the acreage required for a well location under the spacing rules. It is obvious that this is a more or less arbitrary standard by which to reduce the allowable of the well drilled upon the small tract.

"To illustrate: If the spacing regulations provided for 20-acre well locations, and the small tract was only one-tenth of an acre in size, the small tract would receive an allowable of a little more than one-half of the allowable of a well with the same potential drilled upon a 20-acre tract although the small tract would be only one two-hundredth the size of the latter tract. No one would seriously contend that such an allowable would not enable the well on the small tract to produce many times the amount of oil actually in place beneath the small tract. The issue of confiscation would clearly be raised unless adjacent operators were permitted to drill wells as exceptions to the spacing rule so as to counteract this drainage.

"The same objections can thus be raised to this second plan as were raised to the first plan, although to a lesser degree. In the case of small tracts that are only slightly smaller than the area required for a well location under the spacing rules, this second plan works fairly satisfactorily, but in the case of very small tracts it must either result in confiscation or in the drilling of numerous unnecessary wells. Obviously if applied to a field with conditions similar to those existing in the East Texas field it would do very little to eliminate the drilling of unnecessary wells.

"Furthermore, in applying this second plan, the marginal well allowance is apparently always given to the well on the small tract no matter how small the tract may be. The result is that in any field where there is very little spread between the highest allowable given to a well drilled in accordance with the spacing rules and the marginal well allowance, the well drilled on the small tract will be permitted to produce practically as much as wells drilled in accordance with the rule. In a field where this is true the amount of reduction suffered by the well on the small tract is so unsubstantial as to frustrate the entire purpose of this second plan.

"Both of these first two plans proceed upon the presumption that every small tract not created for the purpose of evading the spacing rule is entitled to one well as a matter of right. It is inevitable that the first plan will lead to the drilling of numerous unnecessary wells, if confiscation is to be avoided, and the same is true of the second plan where very small tracts exist, or where the marginal well allowance closely approaches the allowable given to wells drilled in accordance with the spacing rule.

"A third plan has been adopted by the legislatures of the States of New Mexico,[82] and Oklahoma,[83] and Louisiana,[84] which proceeds upon an entirely different premise. The small tract which cannot meet the requirements of the spacing rule is denied a well. In order to prevent the confiscation of the oil beneath the small tract, a provision is made whereby the small tract may be pooled with adjacent tracts and share in the production from those tracts upon an equitable basis. The plan is very similar to the forced pooling of all of the lots within a city block which was first upheld in *Marrs* v. *City of Oxford*,[85] and which has since been upheld in other instances as applied to small tracts within cities. A similar plan was used by the city of Houston, and both the city ordinance[86] and the railroad commission order[87] providing for pooling in accordance with the terms of the city ordinance were sustained as valid.

"In a recent case, *Patterson* v. *Stanolind Oil & Gas Co.*,[88] the validity of the Oklahoma statute and the order of its administrative agency applying this plan of solution to a small tract in a rural area was upheld. From a newspaper account it appears that an effort is being made to carry this important test case to the United States Supreme Court. A decision by that court would be of great value to the oil-producing States as indicating the extent to which the police power may be exerted in solving the small-tract problem. There would seem to be every reason for believing that the holding of the Oklahoma Supreme Court will be sustained.

"The United States Supreme Court, by denying a writ of certiorari in the *Marrs case*, gave approval to this type of pooling regulation as applied to city property. It is true that other police-power purposes are involved in the case of city property from the police-power purposes involved in a similar regulation applied to rural property. Nevertheless, the proper control of the spacing of wells has been sustained as a valid exercise of the police power, and, if pooling of small tracts in rural areas is reasonably necessary to accomplish this valid police-power purpose, the regulation should be sustained.

"This third method of solving the small-tract problem has never been applied in Texas except as to city property. There seems to be some difference of opinion as to whether it could be applied in Texas without a change in our present statutes. Article 6014, section (g) of our oil-conservation act contains a provision that 'it is not the intent of this act to require * * * that separately owned properties in any pool be unitized under one management, control or ownership.' While this provision has never been judicially construed, it would seem quite clear that it was directed at the compulsory unit operation plan for an entire oil field. Furthermore, the statute is not worded in terms of a prohibition to the railroad commission; it is worded merely as an expression of intent on the part of the legislature that the statute is not to be construed as required unitization. It is believed that the general power of the railroad commission to control well spacing is not limited by this statutory provision as to render it impossible for the commission to require pooling of a small tract with adjacent tracts in order to maintain a proper well spacing pattern and to eliminate the drilling of unnecessary wells.

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[82] Chap. 72, Sec. 12, Laws of New Mexico, 1935.

[83] Chap. 59, Art. 1, Sec. 3, Session Laws of Oklahoma, 1935.

[84] Act No. 225, Sec. 6, Subdiv. 6, Acts of Louisiana, R. S. 1936.

[85] 32 Fed. (2d) 134, 67 A. L. R. 1336, cert. denied, 280 U. S. 573, 50 Sup. Ct. 29, 74 L. Ed. 625.

[86] *Tysco Oil Co.* v. *Railroad Commission*, 12 F. Supp. 202.

[87] *Tysco Oil Co.* v. *Railroad Commission*, 12 F. Supp. 195.

[88] 77 Pac. (2d) 83.

"Time will not permit a discussion of the various details involved in this third plan of solving the small tract problem. A study of the legislative acts in the three States that have adopted this plan will reveal that these details have been worked out to the satisfaction, apparently, of the operators and landowners in those States.

"There can be no doubt but that this third plan of solving the small-tract problem, or some modification thereof, is the only method that can be adopted which will, under all conditions, prevent both confiscation of property and the drilling of unnecessary wells. It is the only method that can be used which will preserve the uniform spacing pattern that spacing regulations are designed to establish. And it is the only plan by which fair and equitable allowables can be preserved under proration and the marginal well law as the latter is now interpreted. It seems to be the only real solution of the small-tract problem."

## PRODUCTION

### PROGRESS AND TRENDS IN PRODUCTION PRACTICES

#### TECHNOLOGIC RESEARCH

A vast amount of fundamental research is being carried on in oil company, private, and Government laboratories in an effort to learn more about the physical characteristics of oil and gas as they occur in the underground formations and the mechanics of their flow through reservoir sands to wells. Specifically, much studied thought in the laboratory and field is being given to reservoir pressures and temperatures; the examination of subsurface samples of oil; the work that a given volume of reservoir fluid can perform when expanded from reservoir pressure and temperature to atmospheric conditions; the problem of fluid flow through reservoir sands; the "connate" water content of oil sands; and physical examinations of core specimens of the formations penetrated by the wells. Many production practices have been developed from the results of field and laboratory studies, and because of the eagerness of the industry to adopt new and better production methods that usually also prove to be more efficient and economical than those previously in use, there has been a marked advance in recent years in scientific production of naturally flowing, gas lift, and pumping wells.

*Use of subsurface pressure and temperature data on wells.*—Subsurface pressure and temperature measurements now are taken at regular intervals in many fields, and the data resulting from subsurface-pressure surveys are finding widespread application in the estimation of reserves; in planning comprehensive oil-field development programs; in controlling pressure declines and preventing pressure "sinks" in reservoirs; and in determining the extent of the depletion of reservoir energy in producing fields. Comparison of the drop in reservoir pressure or decline in reservoir energy over a period of time and the oil produced during the interval between pressure determinations indicates the efficiency of the producing operations and furnishes a basis upon which estimates of future production can be made. The producing behavior of individual wells can be interpreted from subsurface-pressure measurements obtained while the well is producing, and application of relations found between rates of flow of fluids through sands to wells and differential pressures in the producing sands aids materially in developing better understanding of reservoir performance and the related problem of well spacing.

Subsurface-pressure surveys have proved invaluable in many fields where measurements of formation pressures indicated irregular declines in reservoir pressures and the formation of pressure "sinks" in widely separated parts of the pool. Subsurface-pressure surveys therefore not only provide a means of determining the efficiency of oil-recovery practices in a pool but supply engineering data whereby production rates in different parts of the pool can be adjusted to permit uniform decline of reservoir pressures and the avoidance of low-pressure regions caused by too rapid withdrawal of oil.

Only recently has the importance of bottom-hole pressure data in pumping wells been fully recognized. From these data it is possible to determine whether the quantity of fluid pumped is limited by the capacity of the well to produce or whether the capacity of the pump is greater than necessary to pump the oil as fast as it enters the well, resulting in inefficient pumping operations. Thus, the information acquired from bottom-hole pressure surveys permits making changes in pump operations on a scientific basis, such as changing the size of pumps, length of pumping stroke, or the rate of pumping to balance output with the rate of flow of oil into the well—an optimum condition in pumping wells.

*Pressure-wave methods for determining fluid levels in wells.*—Although subsurface-pressure instruments have been used extensively in production-control work, periodic measurements of pressure in pumping wells interfere with production and consume considerable time. Inasmuch as the height of the fluid level in wells while they are being pumped is an index of the differential pressure in the sands about the wells, and as efficient production requires that the proper fluid level above the pump and the producing formation be maintained during production, simple and quick methods for determining fluid levels in wells without loss of time and production resulting from pulling and running rods and tubing were sought eagerly. During the past few years two different methods for determining fluid levels in wells have been perfected, both of which depend on the recording of echoes in wells. In the operation of one method compressed gas is released into the annular space between the tubing and casing at the wellhead to produce a pressure wave that travels downward in the well and is reflected back by the liquid in the well to a receiver at the wellhead, where the reflected wave is recorded on sensitized charts from which the time interval of the echo is determined.[89]. In the second method sound waves are set up by discharging a cartridge in a pipe fitting connected to the wellhead on the derrick floor.[90] These sound waves pass down the well in the annular space between the tubing and casing and are reflected back to the top by the liquid in the well and recorded on a chart at the wellhead. Minor reflections are recorded from the tubing collars above the liquid in the well, and if the average length of the tubing joints is known the reflection period from tubing collars provides a scale that can be used to compute the distance to the top of the liquid in the well without considering the velocity of sound through the gaseous medium.

Both methods of determining fluid levels have the advantage over methods using subsurface-pressure instruments in that fluid levels can be determined without interfering with pumping operations and at a fraction of the cost of running pressure instruments into and out of wells.

*Sampling and analyzing subsurface samples of oil.*—The physical characteristics of oil change during its passage through the sand to the bottom of the well and on to surface storage owing to liberation of gas from solution in the oil as its pressure and temperature decreases. Consequently to study the nature and energy characteristics of the fluids in reservoirs instruments have been developed to take samples of oil from the bottom of wells, or at any depth between the top and bottom, and bring the samples in the same condition in which they were taken to the wellhead, from where they are transported to the laboratory and examined under controlled conditions.

For several years Bureau of Mines engineers have been collecting samples of oil directly from the bottom or near the bottom of producing wells by means of special equipment and procedures developed at the Petroleum Experiment Station, Bartlesville, Okla. A report by Grandone and Cook,[91] soon to be published, gives a description of the self-closing subsurface oil-sampling instrument and the technique developed for collecting and examining subsurface samples of oil. The report discusses also some of the physical properties of a sample of oil obtained from a producing reservoir to give an idea of the physical properties of an oil in the reservoir under formation pressure and temperature and describes how these properties are determined. The properties of a petroleum-reservoir liquid and its residua also have been studied by Eilerts and coworkers of the Bureau of Mines, and a report [92] giving information applicable to production problems has been published.

The volume of gas dissolved in the oil in reservoir sands and the change in volume of the oil caused by liberation of the gas as the pressure and temperature are reduced in its travel through the sands and up the flow string to the wellhead are factors that must be considered when estimating the quantity of oil recover-

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[89] Walker, C. P., Determination of Fluid Level in Oil Wells by the Pressure-wave Echo Method: Trans. Am. Inst. Min. and Met. Eng., Petroleum Development and Technology, 1937, vol. 123, pp. 32–43.

[90] Jakosky, J. J., Bottom-hole Measurements in Pumping Wells: Am. Inst. Min. and Met. Eng., Tech. Publication 1058, Petroleum Technology, May 1939, pp. 1–23.

[91] Grandone, Peter, and Cook, Alton B., Collecting and Examining Subsurface Samples of Petroleum: Bureau of Mines Tech. Paper in preparation 1939.

[92] Eilerts, Kenneth, Smith, Vincent R., and Cook, Alton B., Properties of a Petroleum-Reservoir Liquid and Its Residua with Applications of the Data to Production Problems: Bureau of Mines, Rept. of Investigations 3474, October 1939, 47 pp.

able from the sands. In 1933 Lindsly[93] showed the oil in the East Texas reservoir was undersaturated with gas at reservoir pressure and temperature and that its volume decreased 30.4 percent when the pressure on the oil was reduced from 1,400 pounds per square inch (reservoir pressure) to atmospheric, and the temperature was lowered from 146° F. (reservoir temperature) to 75° F. (atmospheric temperature). In other words, Lindsly found that 1 barrel of oil in the stock tanks in the East Texas field represented 1,437 barrels of oil in the reservoir.

Since Lindsly pioneered in the study of "bottom hole" samples of crude oil in the East Texas field representative samples of reservoir oil have been collected by Bureau of Mines engineers in other oil-producing areas. From the analyses of these samples the volume of gas at reservoir pressure and temperature and the reductions in oil volume caused by release of pressure and reduction of temperature have been determined. The volume of gas in solution in the oil at reservoir pressure and temperature and the ratio of volume of reservoir liquid (oil in the reservoir) to the volume of residual liquid (oil in the tanks) for a number of typical fields are given in table 13.

TABLE 13.—*Solubility of gas in oil*[1]

| Field | Reservoir pressure, pound per square inch absolute | Saturation pressure of oil at reservoir temperature, pound per square inch absolute | Temperature, °F. (reservoir temperature) | Gas in solution in the oil at saturation pressure and reservoir temperature, cubic feet per barrel of residual oil[2] | Reservoir liquid volume, equivalent to 1 barrel of residual oil, barrels | Shrinkage, percent |
|---|---|---|---|---|---|---|
| Monument, N. Mex | 1, 540 | 1, 540 | 91 | [3] 438 | 1. 197 | 16. 5 |
| Hobbs, N. Mex | 1, 565 | 1, 565 | 95 | [3] 570 | 1. 248 | 19. 9 |
| Lance Creek, Wyo | 2, 091 | 1, 547 | 175 | [4] 511 | 1. 335 | 25. 1 |
| Medicine Bow, Wyo | 2, 385 | 2, 385 | 142 | [3] 2, 190 | 2. 270 | 56. 0 |
| Billings, Okla | 1, 584 | 1, 584 | 147 | [4] 603 | 1. 345 | 25. 7 |
| Oklahoma City, Okla | [5] 1, 300 | 1, 300 | 132 | [4] 468 | 1. 230 | 18. 7 |
| Do | [6] 2, 630 | 2, 630 | 132 | [4] 795 | 1. 346 | 25. 7 |
| Crescent, Okla.[7] | 2, 829 | 2, 829 | 149 | [4] 887 | 1. 404 | 28. 8 |
| Anahuac, Tex | 3, 235 | 3, 235 | 177 | [3] 553 | 1. 285 | 22. 2 |
| (8) | 3, 192 | 3, 192 | 228 | [4] 1, 980 | 2. 360 | 57. 7 |
| Rodessa, La | 2, 400 | 2, 400 | 188 | [4] 620 | 1. 354 | 26. 1 |
| Lerado, Kans.[9] | 1, 515 | 985 | 135 | [4] 436 | 1. 294 | 22. 7 |
| East Texas[10] | 1, 620 | 755 | 146 | [4] 357 | 1. 429 | 30. 0 |

[1] Courtesy of Peter Grandone and A. B. Cook, Bureau of Mines.

[2] Residual oil is defined as that remaining at the end of the gas-liberation process, measured at atmospheric pressure and 60° F.

[3] Data by flash gas-liberation procedure.

[4] Data by differential gas-liberation procedure.

[5] Reservoir pressure in 1933 (Bureau of Mines data).

[6] Data from Bureau of Mines Report of Investigations 3330, Engineering Report on Oklahoma City Oil Field, Oklahoma, by H. B. Hill, E. L. Rawlins, and C. R. Bopp, January 1937, pp. 202–203.

[7] Data from report by Ben E. Lindsly, entitled "A Bureau of Mines Study of a 'Bottom-Hole' Sample from the Crescent Pool, Oklahoma," published in the Petroleum Engineer, Dallas, Tex., February to June (5 installments), 1936.

[8] A well drilled in the Trinity formation of lower Cretaceous age, east Texas–north Louisiana region; data from Bureau of Mines Report of Investigations 3402, Flow Characteristics, Composition, and Some Liquid-Phase Properties of Hydrocarbon Fluids from a "Combination" Well, by C. K. Eilerts and M. A. Schellhardt, 1938, 34 pp.

[9] Data from Bureau of Mines Report of Investigations 3474, Properties of a Petroleum-Reservoir Liquid and Its Residua with Application of the Data to Production Problems, by Kenneth Eilerts, R. Vincent Smith, and Alton B. Cook, 1939, 47 pp.

[10] Data from Bureau of Mines Report of Investigations 3212, A Study of "Bottom-Hole" Samples of East Texas Crude Oil, by Ben E. Lindsly, 1933, 22 pp.

The data in table 13 show that the contraction of oil due to liberation of gas is appreciable and ranges, for the oils given, from 16.5 to almost 56 percent. To neglect the shrinkage factor when estimating reserves or computing recovery efficiencies and to consider, as formerly, that 1 barrel of oil in the tanks at the wellhead represented an equal volume of oil in the reservoir when actually 1

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[93] Lindsly, Ben E., A Study of "Bottom Hole" Samples of East Texas Crude Oil: Bureau of Mines, Rept. of Investigations 3212, 1933, 22 pp.

barrel of the oil in the tanks may represent 2¼ or more barrels of oil in the reservoir leads to overestimation of reserves and underestimation of recovery efficiencies.

Footnote references 3 and 4 in table 13 opposite the figures for the volume of gas in solution in the oil at reservoir pressure and temperature indicate that some of the gas-solubility determinations were made by liberating the gas from the oil differentially and others by the flash gas-liberation process. In the differential gas-liberation process for analyzing reservoir samples of oil for their gas-solubility characteristics the liberated gases are removed from contact with the oil as rapidly as they are released. This type of liberation closely approaches the release of gas from the oil in the underground reservoir. On the other hand, in the flash gas-liberation process the liberated gases remain in intimate contact with the oil throughout the entire range of pressure drop. Flash liberation therefore approximates the manner of gas liberation that occurs in the flow string of a well. In analyzing subsurface samples of oil, differential and flash gas-liberation tests usually are made on each sample. Slightly different volumes of gas are liberated from solution in the oil for various methods of gas liberation; shrinkage factors also differ slightly, and the volumes and compositions of the residual oils are not exactly the same. Both types of gas-liberation analyses therefore must be made to yield the information necessary for complete analysis of the changes an oil undergoes during production.

Ways in which reservoir data may be obtained, analyzed, and used are illustrated in a Bureau of Mines report[94] in which the most striking results of the study of the sample of oil taken from a well in the Crescent pool, Okla., are listed as being:

(1) The shrinkage, under the various conditions described, of 19 to 38 percent in the volume of the oil with reduction of pressure and liberation of gas.
(2) The capacity of the reservoir fluid to do four or five times the work that is represented by the lifting of the fluid from the reservoir to the surface.
(3) The high indicated efficiency (of the order of 90 percent) of the flow in the well.
(4) The large capacity of the fluid at the wellhead to do additional work.

Subsurface pressures increase with the depth of wells, and the physical state of the fluids in deep reservoirs is of concern to producers of deep wells. Investigations show, for example, that under the extremely high pressures in deep wells of certain high gas-oil ratio fields, the gas in reservoirs actually behaves more like a liquid than a gas and seems to have the physical properties of a liquid.[95]

Knowledge of the nature and behavior of the fluids as they exist in deep-seated reservoirs therefore is essential to the efficient production of oil. Only from study of the characteristics of reservoir fluids and pressures and temperatures under which they exist in the sands can the optimum rate of production be determined and efficient use made of the energy associated with the fluids in the reservoir sands. The studies by the Bureau of Mines and by engineers and scientists in oil-company and university laboratories strikingly indicate the desirability of limiting the quantity of gas produced with oil so that a maximum of energy will remain in the reservoir to raise oil in the future. Thus, as a measure toward conserving the Nation's petroleum resources, efficient utilization of reservoir energy in oil production is of vital concern to all oil producers.

*Porosity and permeability characteristics of oil sands.*—Now that core specimens of the strata penetrated by the drill can be obtained successfully from any depth to which a well can be drilled, direct physical measurements of the properties of the formations can be made in the laboratory. Oil zones seldom are uniformly porous from top to bottom, and the permeability—the property of porous mediums that allows fluid to flow through them—does not vary directly with the porosity. The porosity of a sand stratum is its capacity to hold fluids, and the acre-feet of oil in a low-porosity (tight) sand may be only a small fraction of that in a more porous sand stratum immediately above or below. Similarly, the permeability of the producing sand in one part of the vertical section

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[94] Lindsly, Ben E., Bureau of Mines Study of a "Bottom-Hole" Sample from the Crescent Pool, Okla.: Petrol. Eng., Dallas, Tex., February to June (5 installments) 1936.

[95] Sage, B. H., and Lacey, W. N., Formation Volumes and Energy Characteristics of Gas Cap Material from Kettleman Hills Field: Drilling and Production Practice, Am. Petrol. Inst., 1936, pp. 158–170.

of the oil zone may differ manyfold from that in overlying and underlying sections.

The porosity and permeability of sands may differ laterally also, and a sand stratum of certain porosity in one part of the field may have a lesser or greater porosity in another; similarly, permeability of a sand may differ in different parts of a pool.

Porosity measurements are essential in estimating reserves of oil and gas in reservoir sands by the volumetric method; in doing so, however, consideration must be given to the difference between over-all volume of the pore spaces in the sands and the effective porosity. If the pore spaces in a sand are not interconnected, some of the oil trapped in the pore spaces cannot be produced by any known methods other than mining the sands and bringing them to the surface of the ground where the oil is washed or leached from them after crushing or breaking the bond between the individual sand grains. The effective porosity of a sand—the pore space from which oil may flow to the well expressed as a percentage of the bulk volume of the reservoir rock—therefore is less than its actual porosity based upon total volume of pore space, yet it is the effective porosity upon which reserve figures should be based.

During an investigation of the flow of air and natural gas through porous mediums Bureau of Mines engineers made porosity and permeability determinations on cores from wells in 12 States. The results of the tests which are reported in a recent publication[96] show a range of porosity of 7.1 to 35.3 percent and permeability ranging from less than 1 to 3,820 millidarcys.[97]

Of interest are the results of permeability and porosity determinations on a continuous core taken between depths of 5,945 and 6,038 feet in a well in the Rodessa field, Louisiana, inasmuch as they typify variations in permeability and porosity of many oil zones. The data tabulated by Johnson and Taliaferro and repeated here (table 14) show the wide range both in permeability and porosity of the Oolitic sandstone in the Dees-Young horizon of the Rodessa field.

TABLE 14.—*Permeability and porosity of Oolitic sandstone in a well in the Rodessa field, Louisiana*[1]

| Depth, feet | Permeability, millidarcys | Porosity, percent | Depth, feet | Permeability, millidarcys | Porosity, percent |
|---|---|---|---|---|---|
| 5,945 | 309 | 30.7 | 5,995 | 32.5 | 27.7 |
| 5,947 | 224 | 30.3 | 5,999 | 1.70 | 18.0 |
| 5,950 | 234 | 29.2 | 6,001 | 2.17 | 16.3 |
| 5,957 | 354 | 30.5 | 6,003 | 2.54 | 16.0 |
| 5,960 | 208 | 29.2 | 6,005 | 1.61 | 17.1 |
| 5,964 | 196 | 30.2 | 6,007 | 1.36 | 17.5 |
| 5,965 | 260 | 25.6 | 6,009 | .16 | 11.8 |
| 5,967 | 272 | 24.0 | 6,012 | .22 | 12.5 |
| 5,968 | 65.2 | 24.9 | 6,016 | 1.69 | 18.2 |
| 5,970 | 131 | 26.2 | 6,018 | 1.60 | 17.3 |
| 5,971 | 97.9 | 26.8 | 6,019 | .83 | 14.7 |
| 5,973 | 224 | 29.4 | 6,020 | .08 | 10.5 |
| 5,978 | 28.4 | 24.0 | 6,031 | .09 | 10.9 |
| 5,984 | 131 | 27.4 | 6,034 | .68 | 14.1 |
| 5,987 | 151 | 29.4 | 6,036 | .10 | 10.2 |
| 5,990 | 61.3 | 27.0 | 6,038 | .15 | 11.9 |
| 5,993 | 22.1 | 26.3 | | | |

[1] Table taken from Bureau of Mines Technical Paper 592, 1938, p. 55.

The importance of the factors that affect the flow of fluids through reservoir sands and rocks, long recognized by engineers and physicists engaged in studies of oil- and gas-production methods, is becoming increasingly evident to oil producers. Today the wells of progressive operators are not completed by installing perforated casing opposite the entire thickness of oil zone by rule-of-thumb methods but in accordance with good engineering, based on scientific studies of reservoir conditions, fluid characteristics, and the properties (mainly saturation, permeability, and porosity) of the producing zones.

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[96] Johnson, T. W., and Taliaferro, D. B., Flow of Air and Natural Gas Through Porous Media: Bureau of Mines, Tech. Paper 592, 1938, 55 pp.

[97] The unit of permeability commonly used in the petroleum industry is the darcy, which has been defined as the rate of flow, in milliliters per second, of a fluid of 1 centipoise viscosity through a cross section of 1 square centimeter of a porous medium under a pressure gradient of 1 atmosphere (76.0 cm. Hg) per centimeter and conditions of viscous flow. The millidarcy is 0.001 darcy.

### CONTROL OF GAS-OIL RATIOS IN OIL WELLS

Based upon the recognized principle that effective use of the energy available from a natural petroleum reservoir will decrease the cost of recovery and increase the quantity of oil and gas produced ultimately from the pool, control of gas-oil ratios as a means of effecting gas conservation and efficient production of oil is receiving steadily increasing attention by producers of oil. Chokes (flow beans) installed in the wellhead fittings or on the bottom of the flow string in a well provide a ready means for regulating the rate of flow of oil from it, and such control usually determines the volume of gas produced with the oil from the pool. In many flush-producing fields where the conservation problem essentially is one of producing a minimum volume of gas with the allowable quantity of oil, chokes provide an easy means for adjusting pressures in a well and controlling the differential pressures causing oil and gas to flow through the reservoir sands to the wells. In California, in the Gulf coast area, and in certain fields in Oklahoma, where, for mechanical reasons, wells cannot be produced at maximum rates without damaging the well equipment and wellhead fittings, chokes also are used to restrict the oil-production rates so that "floating" sand will not enter the wells. Thus, as differential pressures in reservoir sands can be controlled by changing the flow areas through which the reservoir fluids are produced to retard inflow of sand and rates of oil and gas production can be regulated by this means, choking of wells has become a major factor in efficient production and conservation practices.

*Use of surface chokes.*—Solid-type wellhead chokes with apertures as small as ⅛ to ¼ inch are used on many wells during their flush-producing lives to apply high back pressures on the petroleum-bearing formations. Petroleum technology not yet has advanced sufficiently to permit predicting the optimum-size choke to use on a well, and the most efficient producing rate must be determined from time to time during the well's flowing life by experimentation. Furthermore, as flow conditions and gas-oil ratios in wells vary, frequent changes of choke sizes are necessary to maintain maximum efficient production rates from the wells. Adjustable-type chokes therefore are used on many wells to permit changing the area of the flow passage through them merely by turning an adjustment screw without breaking and making wellhead fittings, as must be done when solid-type chokes are changed.

In many fields where production rates are restricted to a small fraction of well potentials the smallest choke through which a well can produce its daily allowable in 24 hours often will not permit efficient production of oil. Where that condition prevails maximum flowing efficiencies may be attained by decreasing the production periods to 12 hours or less.

*Bottom-hole choking.*—In some fields bottom-hole chokes have proved more effective in reducing gas-oil ratios than flow restrictions applied at the wellheads. Chokes installed in the wells at the bottom of the flow strings do not freeze and plug because of pressure reduction and gas expansion, and there is less emulsification of oil by gas when bottom-hole chokes are used than when surface choking is practiced.

During the past few years the principles of bottom-hole choking have become better understood, and bottom-hole chokes are being used more extensively than even before in gas wells and high gas-oil-ratio oil wells. A recent innovation in bottom-hole choking is the use of the "side-door" choke that utilizes the gas from upper sands to lift oil from a lower oil sand in which little gas is available for lifting the oil to the wellhead. The side-door choke is installed in the tubing opposite the gas sand, and a packer is placed on the tubing below the sand to close the annular space between the tubing and casing and to prevent the gas from exerting a pressure on the lower oil sand. Gas from the upper sand is admitted to the tubing through the side opening in the choke and aids the gas admitted into the bottom of the tubing with the oil to lift the oil to the surface of the ground. During the past year at least 40 of these chokes have been placed in wells in New Mexico fields. Side-door chokes also are being used advantageously in old wells in which upper gas zones were cased off when the wells first were completed and lower sands only were produced. As the pressure in the lower sands becomes depleted the casing opposite the upper gas sand is perforated and the gas is admitted to the tubing through a side-door choke to lift the relatively "dead" oil from the lower sands to the wellhead.

Another development in bottom-hole choking that is finding widespread application in some oil-producing areas is the variable-size bottom-hole choke that is operated automatically by the gas under pressure in the annular space between the tubing and casing. The valve in the choke is controlled by a calibrated spring and opens only when acted upon by a predetermined differential pressure.

### TREATING WELLS WITH ACID

Almost every well drilled into a limestone formation is treated with hydrochloric acid at some time during its producing life. In areas where daily allowable production per well is based upon the well's capacity to produce and operators desire high initial production rates so that their allowables will be maximum, acid treating usually is part of the well-completion process. In old producing areas, treating wells with acid is for the main purpose of increasing the quantity of oil recovered ultimately from the reservoir. For that reason, wells often are treated with acid at frequent intervals throughout their producing lives.

Acid treating has had a far-reaching effect on the petroleum industry in that it has effected a complete change of attitude toward limestone production. The spread of development into such limestone areas as western Kansas, Michigan, Illinois, and northern Louisiana may be ascribed in large measure to the success of acid-treating processes. Many wells drilled into limestone formations in those areas have been commercially productive of oil and gas only as a result of acidizing. In the newly developed Illinois Basin, for example, many wells drilled into the McClosky formation—an oolitic limestone of varying porosity—failed to show as much as a drop of oil until the formation had been treated with acid. Acid treatment of wells also is credited with extending the productive limits of many oil fields in which edge wells incapable of producing commercial quantities of oil have been completed as paying oil wells after acid treatment. Furthermore, many fields in limestone areas that had almost reached their economic producing limit have been rejuvenated and their capacity to produce oil increased by treating them with acid.

Acid treatment of wells to increase the productivity and ultimate recovery of oil and gas is now generally accepted as standard production practice in Michigan, Kansas, Ohio, Illinois, Kentucky, Oklahoma, Texas, and Louisiana, where oil is found in reservoirs of calcareous and dolomitic rock. In some of these areas acidizing has replaced well shooting; or, where the productive limestone formations are very dense, acid treating is used in combination with shooting to increase the production of oil and gas from wells.

According to Heithecker,[98] acid treating has caused marked increase in the ultimate oil recovery of some old and nearly depleted fields of Kansas, owing to cleaning-out action of the acid at the face of the limestone, enlargement of the small drainage channels, and probably penetration of the acid into previously undrained porous strata. Estimates of greater ultimate oil recovery of various groups of wells in Kansas show increased oil recovery of 10,500 to 21,700 barrels per well, and the increased recovery per acre is estimated at 1,000 to 2,400 barrels of oil; all this has been accomplished by the additional cost of only a few hundred dollars per well for acid and treating service.

Although it is known that 1,000 gallons of 15-percent hydrochloric acid will dissolve about 1,800 pounds or 11 cubic feet of limestone rock, there is no definite rule to govern the quantity of acid to be used for treating an oil well. In some wells a single treatment of 1,000 gallons of acid has been beneficial in increasing the rate of flow of oil into the well and in others, according to Heithecker,[99] as much as 24,000 gallons of acid (volume equivalent to three large railroad tank cars) have been used during stage or multiple treating, the first charge usually being 4,000, the second 8,000, and the third 12,000 gallons.

The practice of acidizing wells has grown phenomenally in the past 5 years, and at present about 10,000 wells are treated annually, requiring approximately 25,000,000 gallons of acid.[1] The rapid development of acid treating in recent years may be ascribed to the development of means for minimizing the corrosive action of the acid on casing in the well, improved technique by contract service agencies, and far-reaching results in increased oil production.

Acid follows the path of least resistance in a well and sometimes enters depleted or thief zones and stimulates the flow of water into the wells. As it is desirable to confine the action of the acid only to the oil-bearing formation organic gels sometimes are used to control and adapt the treatment to special well conditions. This is accomplished by blanketing or plugging with organic

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[98] Heithecker, R. E., Effect of Acid Treatment upon the Ultimate Recovery of Oil from Some Limestone Fields of Kansas: Bureau of Mines Rept. of Investigations 3445, 1939, p. 41.

[99] Heithecker, R. E., Work cited in footnote 98, p. 5.

[1] Kiessling, O. E., Rogers, H. O., and others, Technology, Employment and Output per Man in Petroleum and Natural Gas Production: WPA National Research Project, in cooperation with the U. S. Bureau of Mines, Report No. E–10, July 1939, p. 150.

gels the formations that acid is not to contact. The organic material is mixed with a type of bacteria to form a colloidal suspension that is pumped into the well ahead of the acid. Within one-half hour the suspension jells, and the well then is acidized while the troublesome formations are protected by the jelly plug. Within 24 to 48 hours, depending on the temperature in the well, the jellylike substance is consumed by the bacteria and liquefied so that it can be bailed, swabbed, or pumped from the well.

### PRODUCING CONDENSATE "DISTILLATE" TYPE FIELDS

One of the results of deeper drilling has been the discovery of an increasing number of fields of the so-called "distillate" or "condensate" type in which small quantities of liquefiable hydrocarbons—seldom more than 60 to 70 barrels per acre-foot of sand—under relatively high formation pressures exist wholly or predominantly in the gas phase. When a condensate-type reservoir is punctured by the drill and the equilibrium pressure within the reservoir is disturbed by withdrawing fluids through the well only a small reduction in the pressure about the well results in the formation in the reservoir of a liquid condensate from the gas. As the pool is developed further by the drilling of additional wells and the reservoir pressure declines still more, because of withdrawal of fluid through the wells, increasing quantities of the heavier hydrocarbon vapors condense in the reservoir even though the temperature essentially remains the same. This type of liquid formation, upon lowering of pressure, falls within the class of physical phenomena pertaining to two-phase (gas and liquid) systems covered by the broad term *retrograde condensation*.[2] These phenomena have been the subject of considerable research in laboratories and in the field. Operation of distillate-type fields has shown that the rate of decline in pressure does not affect the quantity of condensate formed within the reservoir and that only the magnitude of decline affects condensation. Operators in distillate-type pools therefore are confronted with the problem of operating their wells so that the pressure drop in the reservoir is the minimum necessary to move the fluids in the reservoir to the wells. In other words, experience has shown that for maximum ultimate recovery of the condensable contents of the reservoir the decline in reservoir pressure during production should be minimum, otherwise the wells ultimately produce only dry gas, and the condensate content of the reservoir gas is lost in the formation owing to premature condensation.

The low saturation of the condensate in condensate-type reservoirs precludes accumulation of enough liquid volume to flow to the well; in consequence, the condensed liquid is finely diffused throughout the reservoir, and much of it is never recovered. Patten and Ivey[3] mention the La Blanca field, Tex., as a classic example of this form of waste in the reservoir. In this field the original reservoir pressure was 4,200 pounds per square inch, and there were 18 barrels of condensate in every million cubic feet of gas produced. Production of large quantities of gas from the field caused the reservoir pressure to decline rapidly. When the reservoir pressure reached 3,800 pounds per square inch only 9 barrels of condensate were produced per million cubic feet of gas, and when the reservoir pressure had declined to 2,180 pounds per square inch the quantity of condensate produced was only 2.6 barrels per million cubic feet. With every pound drop in pressure the condensate content of the gas produced from a "distillate" type pool decreases until finally the quantity of liquefiable fractions in the gas at the wellhead becomes so small that the wells no longer can be operated profitably for liquid products alone. As the market for gas in many areas where condensate-type pools are being produced is limited, the operator usually depends for revenue from the wells solely on the income derived from the sale of the liquid products of the well. Thus he is confronted with the problem of producing the reservoir to yield the maximum quantity of liquid from his wells, and as previously mentioned this can be obtained only by maintaining the reservoir pressure.

The return of residue gas from the reservoir has proved a satisfactory and economical way to maintain reservoir pressures where one operator controls the oil and gas rights to a pool or where all the operators in a common pool agree to cooperate in a program of pressure maintenance. Because of the difficulties in maintaining the pressure in reservoirs by individually practiced production

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[2] Sage, B. H., Lacey, W. N., and Schaafsma, J. G., Behavior of Hydrocarbon Mixtures Illustrated by a Simple Case: Am. Petrol. Inst. Production Bull. 212, 1933, p. 124.

[3] Patten, F. V. L., and Ivey, Denny C., Phase Equilibria in High Pressure Condensate Wells: Oil Weekly, Dec. 12, 1938, p. 20.

control and in returning gas to the producing zone in fields where a large number of operators own the oil and gas rights in a common pool, some form of unit operation is needed for most condensate-type pools. As the fluids in the reservoir predominately are in the gas phase the reservoir should be developed as a gas field and recommended maximum drilling density, according to Foran,[4] should be from 150 to over 300 acres per well depending on the condensate content of the reservoir gas, reservoir pressure, and the thickness of the producing sand. As the producing sands in condensate-type fields usually are only a few feet thick and the initial reserve ranges from only about 20 to 75 barrels of condensable products per acre-foot, well spaced closer than the recommended minimum distance can never pay out, and only through unit operation can such fields be operated profitably.

### TRENDS IN GAS-LIFT OPERATIONS

As a result of important advances in the design of gas-lift equipment and methods of operation the gas lift is being used more widely than ever before as a transitional method of production between natural flow and mechanical pumping. Various types of flow valves have been devised to adapt gas lift to small producing wells and to increase the efficiency of the gas lift in large wells. Formerly all the gas used in gas-lifting oil in wells was introduced into the flow tubing at its lower end; newly developed valves now permit gas to enter the tubing at various points along its length, so that the well fluid actually is lifted in stages instead of as one long column by the energy of the formation gas, assisted by the gas introduced under pressure at the wellhead into the annular space between the tubing and casing. Generally 3 to 10 flow valves are installed in the tubing, the number depending on such factors as the productivity of the wells, rate of production, quantity of water produced with the oil, injection pressure of the gas, and bottom-hole pressure. Prior to the development of flow valves the pressure required to start a well flowing by gas lift usually was much higher than the working pressure, but with the new-type flow equipment the gas is injected into the tubing at intervals along its length, and the kick-off (starting) pressure and the working pressure usually are the same.

Before flow valves were developed to their present stage of practicability it was not possible to obtain production from small wells having low bottom-hole pressures by means of the gas lift. The development of flow-valve equipment, however, has made it possible to obtain production from almost all types of wells by gas lift, and thus the usefulness of the method for lifting oil in wells has been extended greatly as wells now can be operated economically by gas lift long after they have reached the stage at which mechanical pumping formerly was necessary.

On the basis of earlier experience with gas-lift operations, the general conception of many operators, as Rees[5] points out, has been that gas lift was an expensive method of operating an oil well. Formerly, as was done in the Corsicana, Seminole, El Dorado, and other oil fields during their flush-production lives, the gas lift was used mainly to increase the quantity of oil that could be produced by natural flow, and the result generally was to cause rapid encroachment of water which later had to be lifted at high cost. By modern gas-lift methods wells can be operated so as to retard water encroachment rather than to allow an excessive volume of water to be produced with the oil. However, as has been proved, it is possible also to produce economically large quantities of water with gas lift where entrance of water into wells cannot be remedied. Shaw[6] points out that wells producing large quantities of fluid ranging from 2,000 to 20,000 barrels per day containing only ½ to 3 percent oil can be operated at a profit under favorable lifting conditions. Shaw points out also that the trend in producing practice is toward more general use of gas lift for operating small wells for the purpose of reducing equipment, installation, and operating costs to a minimum. Drastic restriction of production rates in many recently discovered fields in Texas and the need for obtaining production economically from low-capacity wells have been largely responsible for the trend toward increasing use of the gas lift for lifting oil.

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[4] Foran, E. V., Deep Drilling and Its Relation to the Characteristics of Condensate Production: Oil Weekly, July 31, 1939, p. 106.

[5] Rees, W. N., Gas Lift as a Production Method in East Texas: Oil Weekly, Feb. 13, 1939, p. 13.

[6] Shaw, S. F., Progressive Trends in Gas-Lift Operations: Petrol. Eng., Midyear 1939, p. 29.

### DEEP WELL PUMPING

Producing oil efficiently and economically from deep wells after they no longer flow naturally or by gas lift is a problem of major concern to oil producers. Pumping of oil from wells becomes increasingly difficult and costly with increasing heights of lift and although important advances have been made in the design and efficiency of conventional plunger pumps much experimental work nevertheless has been done in the development of other types of pumps, such as the electric submersible and the hydraulic pump. Recent progress in pumping technology is reflected in the fact that lifting oil from depths of 7,000 to 8,000 feet no longer is unusual,[7] but because the problem of lifting oil from depths below 10,000 feet soon is likely to be one that demands the attention of the industry, a considerable amount of study already is being given to this future problem.

The walking beam as the oscillator of sucker rods in wells, rapidly is being superseded in many oil-producing areas by portable floor-type pumping units capable of handling heavy loads, with the prime mover an integral part of the unit. Tapered sucker-rod strings with ⅞-inch rods in the upper and ¾-inch rods in the lower section are used when the pumps are installed 5,000 or more feet below the derrick floor; strings composed of 1-inch rods in the top, ⅞-inch in the middle, and ¾-inch in the bottom section are used in wells producing from depths of 7,500 to 8,000 feet.

It is now generally recognized that thorough analysis of the operating characteristics of well pumps is essential for maximum production efficiency, and a number of scientific instruments have been developed to diagnose pumping-well problems and furnish information on well performance, operating loads, power requirements, optimum pumping speed, length of stroke, size and position of the working barrel, and other controllable conditions.[8]

The pump dynagraph—the most recent development in well-testing devices—records variations in the plunger load at all points in the stroke from which the magnitude of the maximum loads on the upstroke and minimum loads on the downstroke may be determined. Correlation of data obtained with the pump dynagraph with those obtained by a dynamometer, which measures the horsepower at the polish rod and the efficiency of the surface equipment, gives a relatively complete story of the operation of subsurface pumping equipment.

In studying pumping wells subsurface pressure recorders are used to determine their potentials and productivity. In making a test the pressure-recording instrument is suspended in the well attached to the lower end of the sucker rods below the standing valve of the pump. After the well has been pumped slowly for a short time it is pumped for 12 hours at the highest rate practical. The pump then is raised or lowered in the well and run at two different rates until equilibrium between pressure and rate of production is reached. Gages of oil and water production are taken during the test, and the volume of gas produced is measured. The static pressure of the reservoir about the well is recorded when the instrument is first run into the well, while the well is standing, and thus three points are obtained on the well's production-pressure performance curve. From these points it is possible to predict the well's potential and to determine its productivity index.[9] Fluid level devices also provide a method for determining the productivity index and well potential.

The beneficial results of well-performance tests are illustrated by the experience of an operator in Kansas on whose property, according to Taylor,[10] about 80,000 barrels of fluid per month was being produced at a cost of $2,100. Breaks in sucker rods occurred on an average of once a day, and individual well studies were made to determine whether the producing operations were the cause of excessive rod breakage, whether they could be minimized, and whether the efficiency of pumping could be improved. In consequence, corrections in pumping conditions were made, and in 6 months lifting costs were reduced to $685 per month or 32.6 percent. Sucker-rod strings parted only on the average of once a month, and monthly production of fluid increased to 90,000 barrels.

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[7] The deepest well now being pumped with sucker rods is in the Rosecrans field, Calif. It is producing about 90 barrels of oil a day from a depth of 8,315 feet.

[8] Clark, Ned, Danberg, H. F., and Kartzke, P. J., The Study of Pumping-Well Problems: Am. Petrol. Inst., Drilling and Production Practice, 1938, p. 209.

[9] The productivity index of a well shows the well's capacity to produce oil in barrels per 24 hours per 1 pound per square inch drop in pressure between the formation and the well.

[10] Taylor, Frank B., Lowering Liftiug Costs Through Well Studies: Oil Weekly, July 13, 1936, p. 52.

Pumping directionally drilled wells (slant holes) economically presents a problem to the industry which, however, is being solved satisfactorily as more experience is being gained in slant-hole pumping. Slant wells averaging 4,300 feet in depth and deviating 15° to 62° from the vertical[11] now are being pumped successfully at Huntington Beach, Calif. Despite the high angle of inclination of the wells production costs are not more than 50 percent higher than usual pumping costs, even when it is considered that the life of the underground well equipment will be briefer than that in vertical wells.

Pneumatic pumping cylinders with single-acting pistons now are used in some fields for pumping deep wells where beam pumping with its limited length of stroke and sudden reversal of stresses in sucker rods has not proved entirely successful. Pneumatic pumping cylinders are suspended centrally over the well hole and connected directly to the sucker rods that actuate conventional-type plunger pumps in the wells. Compressed air or gas is used as the power medium. The pumphead is equipped with controls by means of which the speed of the upstroke and downstroke can be varied independently of one another—a factor of considerable importance, particularly in long-stroke pumping such as is being accomplished at one well in the El Segundo field, Calif., where oil is lifted from a depth of 7,070 feet by a 25-foot pump with a 2-inch plunger having a travel of 15 feet.

Rodless, hydraulically operated pumps continue to receive extensive study, and several new designs are being tested at the present time. The hydraulic pumps in use are actuated by filtered oil pumped under pressure to a fluid-actuated engine direct-connected to a reciprocating, double-acting pump installed in the well. In the Kettleman Hills field, Calif., a well is producing from a depth of 8,600 feet by means of a hydraulic pump of this type. Multiple-well pumping with hydraulic pumps also was introduced in some California fields recently. For their operation, a central pumping plant or power station supplies the activating oil through a main header and branch lines to each well where the operating speeds of the pumps are controlled by needle valves.

The multistage centrifugal pump direct-connected to an electric motor has given successful performance in some fields, and in the Oklahoma City field, Okla., combination arrangements of the gas lift and the centrifugal pump are being used extensively. Large-capacity, bottom-hole, electrically driven centrifugal pumps lift the oil about 1,000 feet above the bottom of the hole, and the gas lift raises it the remaining 5,000 feet to the well head. This combination method of lifting oil in wells has increased the oil potential to more than 5,000 barrels per day in some wells that ordinarily could not be made to produce more than 500 barrels of oil daily.[12]

Advanced pumping methods also have been adopted in fields where the oil-producing formations lie at intermediate depths. Marked improvements also have been made in individual field pumping units, in back-side crank units that have proved especially successful where wells are closely spaced, and in central-power pumping equipment where heavy-type powers successfully pump 6 to 20 wells of medium depth.

Improvements in the design and construction of central powers have made possible the pumping of deeper wells than formerly with this type of equipment. Many of the improvements in central-power design have resulted from information obtained from dynamometer tests of the pumping equipment and studies using notched celluloid hook-off bars for detecting the nature of the stresses in the bars by means of photoelastic analysis, utilizing polarized light.[13]

### METERING OIL AT PRODUCING WELLS

A new development that is being used extensively in fields of California, Texas, and Louisiana is the metering of oil from wells by displacement-type meters. In the Tepetate field, La., for example, oil (also gas) is metered under pressure at a central metering station, and thus the need for storage tanks at the wells is eliminated. In contrast, a separate meter is used at each well in the Kettleman Hills field, Calif., where metering of oil is common practice. Notable economies in measuring the oil produced from individual wells have been effected through the use of meters. Separate oil-gas separators and individual tanks for gaging

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[11] Weaver, D. K., Pumping Slant Holes at Huntington Beach: Am. Petrol. Inst., Drilling and Production Practice, 1937, pp. 138–147.

[12] Mills, Brad, Progress in Engineering: Oil Weekly, Feb. 7, 1938, p. 44.

[13] Mills, Kenneth N., Analysis of Stresses in Hook-offs for Wells: Petrol. Eng., October 1938, p. 27.

the oil at every well in the field are not needed when oil meters are used, as the oil, after passing through the meters, flows to a centrally placed separator or group of separators and then to the lease storage-tanks.

### PREVENTING AND TREATING CRUDE-OIL EMULSIONS

Emulsions of oil and water are among the most serious causes of waste in the oil fields, and the industry has spend millions of dollars and still is spending large sums in dehydrating emulsified crude petroleum to obtain merchantable oil. Most oil fields have water in the extraneous parts of the reservoir, and during production of oil from the pool the water encroaches upon the oil-bearing parts of the structure, eventually reaching the wells. Water may enter a well from other sources also—from water-bearing strata above or below the oil-producing sands or as a result of ineffective water shut-offs, corroded or leaky casing, or drilling into water-bearing sands immediately below the oil zone. When water enters a well from which oil is being produced mechanical agitation of the water with the oil causes dispersion of one liquid in the other to form emulsions (cut oil).

Much thought has been given to methods of treating oil-field emulsions, and in consequence of the knowledge gained through continued scientific research substantial improvements have been made in technique in recent years. Outstanding advances have been achieved in formulating chemical-treating agents and in applying electrical methods of dehydrating crude-oil emulsions. These agents and methods and general improvements in the design of plants and the use of automatic control devices have increased the efficiency of treating methods, and treating costs have been reduced.[14]

In recent years there has been growing realization of the importance of emulsion-preventative measures, and much has been done to determine the sources of emulsions and perfect methods of eliminating or at least reducing the degree of emulsification. Studies of the problem show that certain methods of well and field operation and application of remedial measures to faulty wells frequently will modify or entirely prevent emulsification of oil-water mixtures.

The formation of oil-water emulsions in flowing and gas-lift wells frequently can be prevented by controlling the flowing pressures so that the oil is produced with the minimum gas-oil ratio, or by using large-diameter flow tubes to reduce flowing velocities and minimize agitation of the fluids in the eductor tubes. Wellhead fittings—chokes, valves, tees, and elbows—are sources of emulsification in flowing and gas-lift wells unless they are properly designed and installed to prevent violent agitation of the fluids passing through them.

In pumping wells emulsification of oil-water mixtures is minimized by using oversize standing valves in pumps; excluding gas from pumps; submerging pumps at the proper level below the surface of the fluid in the well; spacing plungers properly; and operating pumps at a speed and with a length of stroke which, by trial and error, have proved most efficient in preventing the formation of emulsions.

In wells where remedial measures or changes in equipment and operation fail to reduce the quantity of emulsion, treating chemicals injected into the flow stream frequently minimize and often prevent the formation of emulsions. Emulsification of oil and water, however, can be prevented only to a limited extent, and the treatment of emulsions continues to be an operating problem of major importance in the oil fields.

### DISPOSAL OF OIL-FIELD BRINES [15]

At some time during the productive life of most oil fields brines (salt waters) are produced with oil in quantities varying considerably with the characteristics of the oil-bearing formations, methods of production, and age of the producing wells. Greater quantities of brine usually are produced from limestone reservoirs than from those comprising sandstone formations; negligible quantities ordinarily are produced from recently completed wells in new fields, but as the fields grow older increasingly greater quantities of brine ordinarily are produced with the oil. Although improved production practices and repair work on old wells tend to hold back the brines, in those fields where brines underlie

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[14] Shea, G. B., Practice and Methods of Preventing and Treating Crude-Oil Emulsions: Bureau of Mines Bull. 417, 1939, 106 pp.

[15] In the preparation of this section on disposal of oil-field brines, the assistance of C. J. Wilhelm, petroleum engineer, and S. S. Taylor, associate petroleum engineer, Bureau of Mines, Bartlesville, Okla., is gratefully acknowledged.

the oil in the extraneous parts of the oil-bearing reservoirs the wells eventually "go to water."

In the fall of 1938 Bureau of Mines engineers estimated that in the Mid-Continent and Gulf coast oil fields approximately 10,000,000 barrels of brine was being produced daily—about 3 barrels of brine for every barrel of oil. The disposal of such large quantities of brine constitutes a problem of vital concern to many oil producers, and although marked progress has been made in recent years, much remains to be learned before the problem of brine disposal is solved.

The three principal methods used for disposing of brines are: (1) Impounding in evaporation ponds; (2) controlled diversion into surface waters; and (3) injection into subsurface formations containing mineralized waters. In the use of these three methods positive elimination of destructive mineralization of potable water is accomplished only by properly controlled diversion into surface waters and by injection of the brines into subsurface formations, except rarely where the concentrated brines in evaporation ponds are retained in restricted areas by impervious surface formations.

Controlled diversion of brines into surface waters is practiced extensively in Gulf Coast areas where enough fresh run-off water is available to dilute the brines. In many inland States, however, diversion of brines into surface streams is prohibited by law, and other means of disposal are necessary. Along the Pacific coast and in the areas bordering on the Gulf of Mexico the problem of disposing of oil-field brines is relatively simple, as the brines can be run directly into the ocean, bays, and bayous after being freed of oil and other oil-field wastes.

Decided progress is being made in recent years toward solution of difficulties encountered in subsurface injection of brines. Much of the pioneer research in brine disposal has been carried on by the Bureau of Mines in cooperation with the Kansas State Board of Health, the State of Oklahoma, and oil companies. Technical studies of subsurface disposal have been concentrated in Kansas[16] and Oklahoma oil-producing areas in the past because of the vital importance of positively eliminating the mineralization of potable waters in those States. The high permeability of surface formations in many of the oil-producing areas of Kansas and Oklahoma precludes the use of natural surface storage and evaporation of brines, and as there is limited rainfall, and water for domestic and industrial uses largely is impounded in reservoirs and drawn from surface streams, the quantity of brine that can be diverted into surface streams is limited.

Mineralization of potable water often is caused by improper plugging of wells upon abandonment, permitting migration of brines from one formation to another. If the hydrostatic pressure in the brine-bearing formation is high enough the migrating brine may reach the surface of the ground through improperly abandoned wells and contaminate surface fresh waters. Often the migrating brine does not reach the surface of the ground but enters the fresh-water horizons below the ground surface, and evidence of such migration is obtained only when the brine reaches a fresh-water well, often only after considerable damage has been done.[17]

Thus disposal of brine in subsurface formations presents many technical and economic problems. In some areas suitable underground formations are not permeable enough to permit injection of the necessary quantities of brine, and even where permeable formations are available it is necessary usually to condition the brine before injection to prevent clogging of the formations by salts precipitated out of solution and materials carried in suspension in the brine.[18]

In general, plants in the Mid-Continent fields for conditioning brines for subsurface disposal are of three types—closed, open, and semiclosed.[19] In the

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[16] Wilhelm, C. J., and Schmidt, Ludwig, Preliminary Report on the Disposal of Oil-Field Brines in the Ritz-Canton Oil Field, McPherson County, Kans.: Bureau of Mines Rept. of Investigations 3297, 1935, 20 pp.

Wilhelm, C. J., Thorne, H. M., and Pryor, M. F., Disposal of Oil-Field Brines in the Arkansas River Drainage Area in Western Kansas: Bureau of Mines Rept. of Investigations 3318, 1936, 28 pp.

[17] Schmidt, Ludwig, and Wilhelm, C. J., Contamination of Domestic Water Supplies by Inadequate Plugging Methods or Faulty Casing: Kansas State Board of Health, a cooperative report by the Bureau of Mines and the Kansas State Board of Health, 1935, 15 pp.

Wilhelm, C. J., Protection of Fresh-Water Horizons in Oil-Producing Areas (with Special Reference to Kansas): Presented at the 29th Annual Meeting of the Kansas Engineering Society, Topeka, Kans., February 11, 1937, and published by the Kansas State Board of Health with permission of the Director, Bureau of Mines, 15 pp.

[18] Taylor, Sam S., Christianson, L. F., Application of Sand Filters to Oil-Field Brine-Disposal Systems: Bureau of Mines Rept. of Investigations 3334, 1937, 28 pp.

[19] Taylor, Sam S., Wilhelm, C. J., and Holliman, W. C., Typical Oil-Field Brine-Conditioning Systems: Preparing Brine for Subsurface Injection: Bureau of Mines Rept. of Investigations 3434, 1939, 71 pp.

closed-type system the brines produced with oil flow through tanks and auxiliary equipment to the disposal well without being exposed at any time to the atmosphere. Thus, all or a large part of the gases are retained in solution in the brine. In the open-type system the gases originally in solution in the brines are released to the atmosphere by aeration. In the semiclosed type there is neither complete exclusion of air nor complete retention of dissolved gases originally in the brine.

Conditioning brines for injection into subsurface formations is expensive, and in many stripper areas the additional expense to the producer in disposing of oil-field brines hastens the time when operating costs cause him to abandon his properties. Premature abandonment of wells and properties because of the high cost of brine disposal results in the loss of large quantities of oil that otherwise might be recovered if brine-disposal costs could be reduced. The disposal of brines therefore is an economic as well as an engineering problem.

Bureau of Mines engineers estimate that capital expenditures by producers of oil for installing brine-disposal equipment—gathering systems, treatment plants, storage facilities, and reconditioning of abandoned wells to make them suitable for disposal purposes—exceed $4,000,000 in Kansas, $1,500,000 in Oklahoma, and $10,000,000 in Texas and Louisiana. Large expenditures for brine disposal also have been made in Michigan; and at one installation in California—a cooperatively owned and operated plant conditioning brines from the Santa Fe Springs, Whittier, Montebello, and Rideout Heights oil fields—the initial investment for plant equipment and gathering lines was approximately $507,000.

Reliable data concerning the quantities of brine passing through disposal systems are not available, but the progress being made in more general adoption of positive disposal of brine by subsurface injection is indicated by the results now being obtained in Kansas and Michigan. In 1935 legislative enactments in Kansas legalized the injection of brine into subsurface formations, and by July 1, 1939, the Kansas Corporation Commission had approved applications for 262 subsurface-disposal wells and 105 projects for repressuring oil-producing formations with salt water or with mixtures of salt water and fresh water. Available information on Michigan indicates that more than 80 percent of the brine produced with oil in that State is being returned to subsurface formations.

## COST OF PRODUCING OIL

Extensive studies by the Petroleum Administrative Board[20] showed that the average cost of producing crude oil in the United States in 1934, based upon company and royalty oil and including royalty value and interest, was 80.3 cents per barrel. During the same period the average selling price of oil was 98.4 cents per barrel, and thus the average operating profit per barrel of oil produced in the United States in 1934, as reflected by those figures, was 18.1 cents.

In 1937 the average cost of producing crude oil in the United States was about 85 cents per barrel; the average in June 1938 probably was a cent or two higher.[21] These figures do not mean that all wells were operated at a profit. In fact, many stripper wells in the Eastern States and elsewhere were operated at a loss. According to Hopkins and Stone at the stripper wells in the Eastern States in particular, where crude-oil prices declined 25 percent in the last 4 months of 1937 and shortly thereafter were reduced further on two occasions, many operators are losing as much as $1 on every barrel of oil produced.

Data for 1937 and 1938 are not available to show in detail the unit cost of crude-oil production and sales value for a large number of districts in the United States. Nevertheless, a review of data compiled by the Petroleum Administrative Board for 1934 (see table 15) is instructive in showing that costs range from those allowing a good profit to those giving a loss of $1 or more per barrel and that many operators in all parts of the United States have lost money on the oil they produced. Furthermore, Hopkins and Stone[22] have compiled estimates on the cost of producing oil in 1937 in three districts and have compared these costs with that obtained for the same districts in 1934.

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[20] Rept. on the Cost of Producing Crude Petroleum, United States Department of the Interior, December 1935, 137 pp.

[21] Hopkins, G. R., and Stone, K. L., Wide Variations Shown in Cost of Oil Production: Oil and Gas Jour., July 14, 1938, p. 15.

[22] Hopkins, G. R., and Stone, K. L., Work cited in footnote 21.

TABLE 15.—*Unit cost of crude-oil production (company-interest oil) and sales value for a number of districts in the United States in 1934*[1]

| Fields | Net cost, including interest at 6 percent on investment, dollars per barrel of oil produced[2] | Average selling price, dollars per barrel of oil sold | Range of costs, dollars per barrel of oil produced[3] | |
|---|---|---|---|---|
| | | | Lowest | Highest |
| Pacific Coast area: | | | | |
| Long Beach-Seal Beach pool | $0.666 | $0.967 | $0.39 | $2.00 |
| Santa Fe Springs pool | .608 | 1.162 | .26 | 2.05 |
| Torrence pool | 1.161 | .764 | .46 | 1.87 |
| Huntington Beach pool | .586 | .924 | .00 | 3.39 |
| Lawndale, Potrero, and Rosecrans pools | .487 | 1.208 | .05 | 2.45 |
| Inglewood and Playa del Rey pools | .650 | .877 | .24 | 1.11 |
| Dominguez pool | .303 | 1.082 | .18 | .70 |
| Brea-Olinda, Coyote Hills, Richfield, Montebello, Whittier, La Habra, Merced Hills, and Baldwin Hills pools | .639 | .945 | .23 | 3.04 |
| Beverly Hills, Salt Lake, and Los Angeles pools | .745 | .972 | .18 | .76 |
| Venture Avenue pool | .529 | 1.019 | .35 | 5.16 |
| Barnsdall, Conejo, Newhall, Ojai, Piru, Santa Paula, Simi, and Sespe pools | .930 | .783 | .57 | 4.73 |
| Santa Barbara, Capitan, Elwood, Goleta, Rincon, and Summerland pools | .874 | 1.042 | .43 | 2.07 |
| Arroya Grande, Casmalia, Cat Canyon, Lompoc, and Santa Maria pools | .743 | .742 | .47 | 2.29 |
| Coalinga pool | .729 | .670 | .16 | 1.08 |
| Kern River, Mount Poso, Round Mountain, and Fruitvale pools | .852 | .574 | .27 | 350.93 |
| Elk Hills, McKittrick, and Wheeler Ridge pools | .755 | .663 | .27 | 1.60 |
| Belridge and Lost Hills pools | .607 | .896 | .33 | 2.34 |
| Midway Sunset and Maricopa pools | .746 | .751 | .25 | 3.53 |
| Kettleman Hills pools | [4] —.123 | 1.077 | .00 | 1.51 |
| Mountain View pool | .501 | .723 | .31 | 1.11 |
| Other and unclassified | 1.314 | .779 | .47 | 4.03 |
| Total, California | .585 | .907 | | |
| Mid-Continent—Gulf area. | | | | |
| Texas: | | | | |
| Panhandle | .856 | .875 | .13 | 3.70 |
| West Texas | .658 | .765 | .22 | 6.45 |
| North Texas | 1.021 | .983 | .23 | 8.38 |
| Central Texas | .823 | .862 | .41 | 1.79 |
| Caldwell, Bastrop, and Guadalupe Counties | .787 | .837 | .34 | 6.88 |
| Other Central Texas | .753 | .972 | .39 | 3.52 |
| Southwest Texas | .861 | .907 | .44 | 6.86 |
| Government Wells pool | .677 | .800 | .35 | 1.23 |
| Texas Gulf Coast | .783 | 1.015 | .13 | 65.27 |
| Eaxt Texas proper | .622 | .998 | .20 | 1.48 |
| Other East Texas | .425 | .956 | .40 | 1.00 |
| Other and unclassified | .901 | .847 | .14 | 5.76 |
| Total, Texas | .704 | .940 | | |
| Oklahoma: | | | | |
| Nowata, Rogers, Craig, and Washington Counties | .937 | .948 | .28 | 3.16 |
| Tulsa and Creek Counties | .967 | 1,001 | .13 | 10.93 |
| McIntosh, Wagoner, and Muskogee Counties | .975 | 1.016 | .52 | 2.03 |
| Okmulgee, Okfuskee, and Hughes Counties | 1.199 | 1.008 | .00 | 7.51 |
| Osage County | 1.026 | 1.019 | .00 | 3.34 |
| Pawnee, Payne, and Lincoln Counties | .909 | 1.049 | .29 | 3.56 |
| Noble, Kay, Logan, Garfield, and Grant Counties | .983 | 1.077 | .41 | 4.49 |
| Burbank pool | 1.159 | 1.026 | .35 | 4.10 |
| Cushing pool | 1.062 | 1.059 | .71 | 3.28 |

[1] Table compiled from data given in table 11, Report on the Cost of Producing Crude Petroleum, issued December 1935, U. S. Department of the Interior, Petroleum Administrative Board, pp. 32–61.

[2] Includes allowances for depletion, depreciation, amortization of intangible development costs, operating expenses, general overhead and administrative costs, interest on invested capital, and revenue obtained from gas sales and miscellaneous sources.

[3] According to the Petroleum Administrative Board, the highest and lowest costs vary widely from the weighted average cost in every pool or district and are mainly significant in showing the wide range of fluctuations. The highest calculated cost usually was that of an operator with small production and exceedingly large charges for such items as dry holes or lease cancelations; the lowest cost was obtained after crediting the cost with sales of gas (see table footnote 4 ), miscellaneous revenue, or an adjustment in accounts that affected prior periods.

[4] Credit for sales of gas produced in the Kettleman Hills field in 1934, resulted in a minus cost for oil produced, after all expenses and interest on investment were deducted from the cost of producing oil for most of the operating companies.

TABLE 15.—*Unit cost of crude-oil production (company-interest oil) and sales value for a number of districts in the United States in 1934*—Continued

| Fields | Net cost, including interest at 6 percent on investment, dollars per barrel of oil produced | Average selling price, dollars per barrel of oil sold | Range of costs, dollars per barrel of oil produced | |
|---|---|---|---|---|
| | | | Lowest | Highest |
| Mid-Continent—Gulf area—Continued. | | | | |
| Oklahoma—Continued. | | | | |
| Oklahoma City pool | $0.835 | $1.025 | $0.44 | $3.76 |
| Healdton and Hewitt pools | .696 | .921 | .27 | 1.43 |
| Seminole pool | .857 | 1.044 | .43 | 5.18 |
| Other pools in Stephens, Cotton, Murray, Carter, Pontotoc, Garvin, Grady, Caddo, Marshall, Comanche, and Jefferson counties | .843 | .887 | .31 | 9.49 |
| Other and unclassified | 1.388 | 1.007 | .62 | 2.65 |
| Total, Oklahoma | .909 | 1.022 | | |
| Kansas: | | | | |
| Butler and Harvey Counties | .730 | .992 | .18 | 36.05 |
| Greenwood and Woodson Counties | 1.076 | 1.031 | .14 | 4.62 |
| East Kansas | .969 | 1.007 | .31 | 7.07 |
| Sedgwick County | 1.006 | 1.063 | .37 | 1.93 |
| Sumner and Cowley Counties | 1.142 | 1.043 | .38 | 4.24 |
| Rice, Reno, Ellsworth, Kingman, Rush, Barton, Russel, Trego, Ellis, and Rooks Counties | .801 | 1.047 | .23 | 12.28 |
| McPherson County | .784 | 1.040 | .36 | 12.15 |
| Other and unclassified | .995 | 1.055 | .03 | 14.83 |
| Total, Kansas | .882 | 1.031 | | |
| Arkansas: | | | | |
| El Dorado pool | 1.209 | .878 | .52 | 2.12 |
| Smackover pool | 1.020 | .702 | .69 | 1.42 |
| Other pools | .910 | .666 | .22 | 6.34 |
| Total, Arkansas | .987 | .695 | | |
| Louisiana: | | | | |
| Red River, De Soto, Elm Grove, Pleasant Hill, Zwolle, and Urania pools | 1.126 | .974 | .31 | 4.03 |
| Haynesville, Homer, Cotton Valley, Sareptia, and Carterville pools | .949 | .927 | .35 | 5.60 |
| Caddo pool | 1.208 | .938 | 1.07 | 1.30 |
| Louisiana Gulf Coast | .753 | .990 | .25 | 4.23 |
| Total, Louisiana | .818 | .982 | | |
| New Mexico: | | | | |
| Hobbs pool | .542 | .750 | .28 | 1.10 |
| Other pools in Eddy and Lea Counties | .625 | .749 | .29 | 2.71 |
| San Juan and McKinley Counties | .648 | .786 | .40 | 2.24 |
| Total, New Mexico | 571 | .755 | | |
| Rocky Mountain area: | | | | |
| Wyoming: | | | | |
| Salt Creek pool | .999 | .995 | .18 | 2.13 |
| Lost Soldier pool | .847 | .880 | .46 | .85 |
| Other pools | 1.144 | .812 | .23 | 14.52 |
| Total, Wyoming | 1.048 | .916 | | |
| Montana: | | | | |
| Cat Creek pool | 1.225 | 1.228 | 1.01 | 1.30 |
| Pondera pool | 1.089 | 1.234 | .63 | 1.98 |
| Kevin-Sunburst pool | .922 | 1.342 | .39 | 1.58 |
| Other pools | 1.337 | 1.378 | .26 | 4.20 |
| Total, Montana | 1.187 | 1.332 | | |
| Colorado: | | | | |
| Fort Collins and Wellington pools | 1.906 | .884 | 1.67 | 4.81 |
| Iles pool | .826 | .900 | .75 | 1.03 |
| Other pools | 1.433 | 1.023 | 1.04 | 2.93 |
| Total, Colorado | 1.216 | .941 | | |

TABLE 15.—*Unit cost of crude-oil production (company-interest oil) and sales value for a number of districts in the United States in 1934*—Continued

| Fields | Net cost, including interest at 6 percent on investment, dollars per barrel of oil produced | Average selling price, dollars per barrel of oil sold | Range of costs, dollars per barrel of oil produced | |
|---|---|---|---|---|
| | | | Lowest | Highest |
| Eastern area: | | | | |
| Illinois | $1.240 | $1.121 | $0.48 | $2.33 |
| Indiana | 1.064 | 1.124 | .28 | 4.43 |
| Ohio | 1.969 | 1.537 | .43 | 4.12 |
| Michigan | .658 | 1.016 | .18 | 7.15 |
| Kentucky: | | | | |
| Western | 1.157 | 1.087 | .65 | 3.90 |
| Eastern | 1.570 | 1.216 | .74 | 3.86 |
| Total, Kentucky | 1.390 | 1.160 | | |
| West Virginia | 2.113 | 2.089 | .63 | 5.70 |
| Pennsylvania | 1.933 | 2.440 | .35 | 11.30 |
| New York | 2.330 | 2.451 | 1.36 | 4.35 |
| Average, all States | .775 | .984 | | |

The three districts selected for the cost analysis were Kansas, Louisiana Gulf, and West Virginia. Kansas was selected because it typified a combination of stripper and prorated flush production of the Mid-Continent; the Louisiana Gulf, because it has the largest production per well per day of any district in the United States; and West Virginia, because all wells in that State can be classed as strippers.

Table 16, compiled from data prepared by Hopkins and Stone, shows for 1934 and 1937 the cost per barrel of oil produced and its sales value in the three selected districts. It shows also the average daily oil production per well for each of the districts.

TABLE 16.—*Average production per well per day, cost per barrel of oil production, and average sales value in three representative districts of the United States, 1934 and 1937*[1]

| District | Year | Average oil production per well per day, barrels | Net cost of production, dollars per barrel of oil produced | Average selling price, dollars per barrel of oil |
|---|---|---|---|---|
| Kansas | 1934 | 6.9 | $0.882 | $1.031 |
| | 1937 | 9.5 | .970 | 1.230 |
| Louisiana Gulf Coast | 1934 | (2) | .753 | .990 |
| | 1937 | (3) | .705 | 1.150 |
| West Virginia | 1934 | .6 | 2.113 | 2.089 |
| | 1937 | .6 | 2.300 | 2.280 |

[1] Compiled from data given by Hopkins and Stone. (See Oil and Gas Jour., July 14, 1938, p. 15.)

[2] In 1934, virtually all production came from wells producing more than 27 barrels of oil a day.

[3] In 1937, the greater part of the production came from wells producing between 200 and 500 barrels of oil a day, with an appreciable percentage coming from wells producing more than 500 barrels of oil a day.

Hopkins and Stone indicate that the average small-stripper operator in Kansas is losing money if his average output per well is less than 1 barrel of oil a day. On the other hand, the average indicated profit from the comparatively few wells producing in excess of 100 barrels of oil a day is estimated at about $0.40 per barrel of oil produced.

It is difficult to comprehend how the average operator in West Virginia can continue in business. The producing wells of West Virginia are uniformly small pumpers with only about 500 out of nearly 19,000 wells producing more than 1 barrel of oil daily. The average net cost per barrel in 1937 is estimated as

$2.30—the average sales price of West Virginia crude oil in 1937 was about $2.28, indicating that the average barrel of oil was produced during the year at a loss of 2 cents. More incongruous is the fact that on March 7, 1938, the price of crude oil was reduced to $1.65 and on June 13, 1938, it was reduced further to $1.40, at which time it was 90 cents below the estimated average cost of production.

How then can operators in West Virginia continue to produce oil when the sales value of the oil is nearly $1 less than the estimated cost of producing a barrel of oil? Hopkins and Stone suggest "presumably by ignoring depletion, depreciation, and all other intangibles, and by cutting operating costs to the bone." The casual visitor to the eastern oil fields, however, will wonder how the operators can reduce their production costs materially because the average operator has about reached the minimum cost of production. Obviously, when the sales price for oil and the actual out-of-pocket cost meet, his only alternative, if these conditions long continue, is for him to abandon his properties with consequent losses in reserves and employment because of economic circumstances.

## OIL RECOVERY FROM RESERVOIR SANDS

The quantity of oil recoverable from petroleum reservoirs continues to be a subject of first interest to executives, engineers, the investing public, and the Nation as a whole for, as stated in an earlier report: [23] "upon that quantity depends in large measure the economic, engineering, and social developments pertaining to a pool or other oil-bearing structure. In a new field the management of companies and individual operators are, or should be, concerned in the quantity of oil that can be recovered from the sands in order to plan development and operating programs wisely so that investment will not overextend return thereon. If change of ownership is involved, equitable evaluation depends not only upon the capital investment and depreciation, but also upon the remaining oil left in the sands which may be recovered upon the reasonable expenditure of additional funds needed to stimulate flow of the remaining recoverable oil from the sands to the wells."

Early engineering estimates indicate that a large percentage of the original oil in the reservoir remained in the partly depleted pore spaces when oil wells reached the point in productive life where for financial or other reasons abandonment seemed necessary. Formerly, however, wells were produced "wide open" and permitted to produce currently all the oil that they could bring to the surface of the ground. Wells in many fields also were located without apparent rhyme or reason other than to place them so that at least one well would be drilled on each land subdivision. The individual with an acre of land in an oil field or the owner of a city lot in a subdivision overlying an oil pool not only demanded that his lessee drill a well on his property but made him produce all the oil he could from the reservoir in as short a time as possible through the well. Companies and operators controlling the development of large holdings usually spaced their wells 1 to 10 acres but had to disregard uniformity of spacing and spacing distances when it became necessary to drill offsets to wells on adjoining properties where such wells along the property lines were more closely spaced.

Early wells were completed without tubing; the casing was utilized for the flow string; in the production of the oil no thought was given to the conservation of reservoir energy; in consequence, energy needed later to produce oil was dissipated early and rapidly. In fact, engineering studies disclose that in many fields wide-open flow was grossly inefficient, and in many of them only a very small percentage of the original was recovered.

Laboratory and field studies show that tubing newly completed wells and producing the wells under back pressure conserves reservoir energy, not only increasing the efficiency of recovery but reducing the cost of lifting oil. Most reservoirs of oil are underlain by water in the extraneous parts of the reservoir, and the water acts as a natural drive to force oil toward the producing wells. In such fields balancing of reservoir withdrawals with the rate of encroachment of water makes possible continuous production of oil under pressures close to those originally in the reservoir, with the volume of gas produced per barrel

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[23] Miller, H. C., and Lindsly, Ben E., Report on Petroleum Development and Production: Petroleum Investigation (U. S. Congress, House of Representatives), Hearing on H. Res. 441, 73d Cong. Recess 1934, pt. II, p. 1214.

of oil approaching that dissolved in the oil in the reservoir. Most of the wells in the East Texas field still flow oil in the liquid phase owing to maintenance of pressure in the reservoir as a result of restrictions placed on the quantity of oil permitted to be produced per day, and engineering studies made recently indicate that the efficiency of extraction from that portion of the field where the oil of the producing formation has been displaced by water has been extremely satisfactory and much higher than generally thought.

Although early producing methods generally are considered to have been inefficient and to have left large quantities of oil in the sands, studies by Bureau of Mines engineers of recoveries in certain fields, now virtually depleted of their recoverable oil, where the oil was backed by water under high head, indicate that in some fields probably as much as 85 percent of the original oil was recovered by natural flow and pumping. Some engineers question the accuracy of the computed recovery percentages, inasmuch as certain factors, including the percentage of original saturation of the sands, volume of gas in solution in the oil, porosity of the sand, its "connate" water content, and the original reservoir pressure were not determined when the fields were developed because methods and equipment for these purposes were unknown at the time. However, liberal allowances, based upon data obtained in similar fields more recently developed, were made for all undetermined factors in the Bureau's computations so that the estimates of recovery efficiencies in the fields studied by Bureau engineers that were produced wide open and now are virtually depleted of their recoverable oil probably were not greatly in error. Laboratory studies substantiate field findings, in that they show that oil recoveries in reservoirs conceivably might be as high as 85 percent in some fields under certain conditions of operation where there is an active natural water drive and sand conditions and water-encroachment rates are favorable for efficient flushing of oil out of the sands.

Appreciating the need for more accurate information than has been obtainable heretofore on the quantity of oil in a sand originally, at any time during its producing life, or after a field has been abandoned because producing operations no longer could be carried on profitably, engineers now are working on the development of coring tools that have for their objective the taking of core specimens of reservoir sand under pressure and uncontaminated by drilling fluids. Two pressure-coring devices of different basic designs already have been constructed,[24] and although both of them still are in the development stage and neither has been successful in taking uncontaminated cores, one has been successful in cutting cores of reservoir formations under medium pressures and bringing them to the surface of the ground under reservoir pressure, and the other has cut several cores, one of which was brought to the wellhead and transported to the laboratory under a pressure of 1,320 pounds per square inch at a temperature of 80° F.

Thus, with various instruments for acquiring reservoir data at their disposal, petroleum engineers soon should have a fund of data on recently developed fields that will permit them to compute more accurately than can be estimated from "post mortem" studies of depleted or nearly depleted reservoirs how much oil actually will be left in the sands when the fields finally are abandoned.

The subject of oil remaining in reservoir sands when fields are abandoned because oil no longer can be recovered at a profit was discussed at length by Miller and Lindsly in a previous report.[25] In compiling the section, Oil Recovery from Reservoir Sands, for that report, published literature was drawn on freely, and the opinions of different engineers and geologists in the industry were sought by correspondence and personal interviews and thoughtfully considered. The need for authentic information on the quantity of oil recoverable by customary producing methods was appreciated in 1934, and in the 5 years since that report was published interest in oil-recovery information has continued at an accelerated rate because of rapid expansion of proration and the increasing extent to which production of oil from the fields of the United States is being curtailed.

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[24] Sewell, B. W., The Carter Pressure Core Barrel, before Division of Production, American Petroleum Institute, Twentieth Annual Meeting, Chicago, Nov 17, 1939. (See Oil and Gas Jour., Nov. 17, 1939, pp. 140–144.)
Taliaferro, D. B., and Heithecker, R. E., Bureau of Mines-A. P. I. Pressure Core Barrel (Progress Report on Its Design and Development): Bureau of Mines Rept. of Investigations 3481, 1939, 20 pp.

[25] Miller, H. C., and Lindsly, Ben E., Work cited in footnote 23, pp. 1214–1226.

From the best information available in 1934 it was concluded that oil-recovery efficiencies range from about 20 to about 60 percent, depending on the field and the manner in which it is operated.

The discovery, within the past 5 years, that petroleum engineers erred in considering that all of the pore space in reservoir sands is filled with oil when, as recent researches show, 50 or more percent may be occupied by water that does not move with the oil to the wells, and that 1 barrel of oil in the reservoir shrinks to less than 1 barrel in the tanks at the wellhead, tends to make questionable many of the early estimates of oil-recovery efficiencies. Furthermore, continuing studies of the characteristics of reservoirs, the physical and chemical properties of the reservoir oil, fluid-energy relations in petroleum-bearing sands and rocks, and other factors inherent to the reservoir, the oil, and the manner of its extraction show that recovery efficiencies—computed on incomplete information as early estimates necessarily had to be—probably in many fields were far too low.

### NEED FOR CONSIDERING "CONNATE" WATER AND THE SOLUBILITY OF GAS IN OIL WHEN ESTIMATING OIL IN PLACE

Until a few years ago, gas, oil, and water in undisturbed reservoirs were considered to be segregated in accordance with their densities. The fact that gas, oil, and water in a bottle adjust themselves in the order of their specific gravities—gas on top, water at the bottom, and oil in between—seemed to be prima facie evidence that similar gravitational adjustment of the fluids took place in natural sand-filled reservoirs. As the forces encouraging gravitational segregation of fluids in natural reservoirs have been active for geologic ages geologists thought for a long time that adjustment of the fluids in reservoirs was complete and believed that the pore spaces in the gas zone of the reservoir were filled with gas and those in the structurally underlying oil zone filled completely with oil; in neither the gas part nor the oil part of the reservoir was water considered to be present.

The fact that many sands produced gas and oil and no noticeable or measurable quantities of water strengthened the theory that if water once was present in the sands it must have vacated completely in favor of the gas and oil. On the other hand, when water was produced from sands in which top, intermediate, bottom, and edge water was absent the source of the water usually was thought to be the circulating fluids used in drilling the wells.

Since equipment has been developed for taking core samples of reservoir sands and methods have been devised for analyzing core specimens for their liquid content the present of water has been noted in sands that otherwise would have been considered as containing only gas and oil. Thus, recent investigations show that fluid disposal in reservoir sands is not entirely in accordance with the gravitational theory of segregation and that in many sands in which water was thought to be absent, as much as, and sometimes more than, 50 percent of the pore space is filled with water.

That water might have entered the sand cores while they were being cut and withdrawn from the wells was investigated, and it was found that when a "tracer material" was added to drilling fluids for measuring the contamination of core samples by water from drilling fluids that in one well in the Dominguez field, California, an average of 38 percent of the pore space of the oil sand was occupied by water other than that coming from the drilling fluids.[26] Tests conducted in other fields, using oil as the circulating medium to avoid the possibility of contaminating the cores with water, also showed that water in varying amounts is present with oil in the pores of oil sands and proved that such water did not enter the sand from the wells.[27]

Thus, in calculating petroleum reserves by the volumetric method, very inaccurate estimates may result if the space volume of the reservoir sands is partly filled with water and the water content is not taken into consideration. Under certain conditions water will be retained by the sands when oil will flow through them freely, mainly because the interfacial tension between water and sand grains is greater than that between oil and sand grains. Accordingly, a well producing

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[26] Pyle, Howard C., and Jones, P. H., Quantitative Determination of the Connate-Water Content of Oil Sands: Am. Petrol. Inst., Drilling and Production Practice, 1936, pp. 171–180.

[27] Lewis, James A., and Horner, William L., Interstitial Water Saturation: Oil Weekly, Oct. 19, 1936, p. 36.

clean oil and no water is no proof that the pore spaces in the sand are entirely free of water.

Early estimates of oil in place in reservoir sands considered the pore spaces in the sands as filled completely with oil. The presence of water in the pore spaces of many oil-producing sands was not suspected because few properly completed wells produced water with the oil during their flush producing lives. Accordingly, for many fields, early estimates of oil in place, as measured by the volumetric content of the pore spaces in sands, probably were too high. Consequently, calculated recovery efficiencies based upon the quantity of oil produced as a percentage of a too-high estimate of oil in place will be lower than the actual percentages of oil recovered. If, for example, the volumetric content of the pore spaces in a sand is computed at 1,500 barrels per acre-foot, production of 500 barrels of oil per acre-foot will signify a recovery efficiency of 33⅓ percent if the pore spaces are considered to contain only oil originally. However, if 40 percent of the pore spaces is assumed to be filled with connate water, each acre-foot of sand contained originally only 900 barrels of oil, and a recovery of 500 barrels of oil per acre-foot would therefore indicate a recovery efficiency of 55½ percent.

Furthermore, in most oil reservoirs, and especially in deep-seated ones under high pressure, a barrel of oil as measured in the tanks on the surface of the ground is equivalent to more than a barrel of oil in the reservoir. As shown in an earlier section of this report, oil in reservoir sands contains gas in solution, and the oil shrinks when produced because gas is liberated from the oil upon the reduction of pressure. In some fields 1¼ barrels of reservoir oil becomes 1 barrel of oil when in the tanks on the surface of the ground. Accordingly, unless the shrinkage factor is taken into consideration, calculated recovery efficiencies based upon volume of pore space in the reservoir and oil produced (as measured at the surface of the ground) will be low. For example, assume 1 barrel of oil measured at the surface of the ground is equivalent to 1¼ barrels of oil underground; then, if the volume of the effective oil-filled pore spaces in 1 acre-foot of sand is equivalent to 1,500 barrels and these pore spaces are filled with oil containing gas in solution under high pressure, a production as measured at the wellhead of 500 barrels of oil per acre-foot actually represents production of 625 barrels of reservoir oil. The efficiency of production therefore will be 41⅔ percent and not 33⅓ percent, as it would have been if shrinkage had not been considered.

If the pore spaces in the sand containing the oil with dissolved gas also contained 40 percent water, there will be, in the cited example, only 900 barrels of oil per acre-foot (as measured in the sand). This volume, in terms of volume measured at the surface of the ground and based upon a shrinkage factor of 20 percent (1¼ barrels of reservoir oil equivalent to 1 barrel of residual oil), will be equivalent to 720 barrels of oil. As it was assumed that 500 barrels of oil (measured in the surface tank) were produced, the efficiency of recovery, on the basis of 40 percent connate water in the sands and an oil-shrinkage factor of 20 percent, will be approximately 69½ percent.

Thus, in some fields where the efficiency of recovery was estimated to be 33⅓ percent because of failure to consider connate water and gas in solution in the oil actually about 70 percent of the oil may have been recovered.

Recent studies in fields where production rates were controlled to the extent that the high-head edgewater encroached into the oil sand at approximately the same rate as the rate of withdrawal of the oil showed that a large percentage (80 to 90 percent and more) of the oil had been recovered from the sand by the encroaching water. Laboratory experiments by Bureau of Mines engineers also showed oil-recovery percentages as high as 85 percent when water displaced the oil in oil-saturated sand. The experiments showed further that in highly permeable (loose) sand higher percentages of oil recovery may be expected than in tight sands, and for any given sand the percentage recovery was slightly greater for rapid rates of flow than for slow rates. This latter finding, which still must be verified by more experimentation, is somewhat contrary to the opinion by many engineers, in that it has been thought for some time that at slow rates of water encroachment oil recoveries would be higher than at more rapid rates.

It would seem to one not familiar with the technology of oil production that petroleum engineers should be able to tell more definitely than they have in the past what percentage of oil is being recovered from reservoirs now undergoing depletion. Petroleum engineering, however, is a relatively new science, and those engaged in petroleum work are handicapped because they are dealing with exceedingly complex fluids in reservoirs they can "see" only through the records of scientific instruments and the results of research. Progress leading toward more accurate estimates of oil-recovery efficiencies definitely is being made, and the accuracy of the estimates is improving in direct proportion to the increase in the fund of knowledge now being accumulated in the course of studies of gas in solution in oil, connate-water content of oil-bearing sand, and other characteristics of reservoir fluids and reservoir rocks.

### RELATION BETWEEN RATE OF PRODUCTION AND RECOVERY

The relation between the rate of production of oil from a reservoir and the reservoir pressure has been clearly demonstrated in the East Texas and other fields in Texas. In these each time the rate of flow from the field was reduced the decline of reservoir pressure was checked.

In discussing the East Texas field, Col. E. O. Thompson, chairman, Interstate Oil Compact Commission and member of the Railroad Commission of Texas, stated in part:[28]

"If the production rate of 900,000 barrels daily (which prevailed from March 10 to July 12, 1933) had been allowed to continue, the average reservoir pressure of the East Texas field would have declined to 760 pounds per square inch during July 1934, and the accumulative production at that time would have been 695,000,000 barrels.

"It is now generally well understood that when gas is allowed to evolve out of solution the viscosity of the oil is increased and the effectiveness of the water flood is decreased as much as 75 percent; and inasmuch as only 695,000,000 barrels would have been produced at that date out of an estimated ultimate recovery of approximately 4 billion barrels, it is obvious that a tremendous waste of crude oil would have occurred in the East Texas field.

"Since the total withdrawal from the field was regulated, however, the bottom-hole pressure decline was arrested, with the result that approximately 1,400,000,000 barrels of oil have been withdrawn from this reservoir; the average pressure as of January 1939 is still approximately 1,107 pounds per square inch, for, roughly, 19,600 of the 25,600 wells are still flowing.

"We have recently made tests of carefully taken cores on the west side of the East Texas field, where oil is no longer produced. These cores had less than 3 percent of the oil saturation remaining in the sand. It is indicated that under this method of operation there is remarkably high recovery."

High recoveries of oil from reservoir sands are obtained in many other fields where advantage is taken of the high-head water in extraneous parts of the oil-bearing sands to maintain the reservoir pressure. Artificial means of maintaining reservoir pressure by returning natural gas produced with the oil back into the sand under pressure also have been successful in increasing the percentage of oil ultimately recoverable from the sands. According to E. O. Bennett, chief engineer, Continental Oil Co.,[29] the average increase in ultimate oil recovery in all pools where pressure maintenance is practiced will be at least 40 percent greater than that obtainable by ordinary methods of pool operation.

Although more pressure-maintenance projects have been started during the past 5 years than during any previous like period, the total number of such projects still is surprisingly limited in view of the advantages of increased recovery efficiencies and decreasing costs resulting from pressure-maintenance operations. More operators do not take greater advantage of the proved, more efficient recovery technique of pressure maintenance because of the difficulties experienced in combining the efforts of all operators in a common pool or in a large area of a field in a pressure-maintenance program. Unless one operator controls a large block in a pool under diversified ownership, he cannot successfully conduct a pressure-maintenance program if his neighbors refuse to cooperate, because the gas returned to the reservoir will migrate and drive oil toward the neighboring areas where no attempt is being made to maintain the reservoir pressure.

A successful pressure-maintenance project and a fine example of the conservation of oil and gas resulting from the maintenance of reservior pressures by the return of residue gas to the formations from which it came originally is

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[28] Thompson, Ernest O., An Administrator's Views on Oil Proration: Oil and Gas Jour., Feb. 23, 1939, p. 47.

[29] Bennett, E. O., Pressure Maintenance: Am. Petrol. Inst., Drilling and Production Practice, 1938, pp. 113–134.

that being carried out in the Cook Ranch pool, Shackelford Co., Tex. In that pool, according to Bennett,[30] utimate recovery of oil, based on a projection of the normal-production curve during the first part of its life, was estimated to be about 7,500,000 barrels—an average of 313 barrels of oil per acre-foot and an indicated recovery of only about 20 percent of the oil originally in the pool. During the 10½ years from the start of gas injection—July 1927 to the end of 1937—10,342,465,000 cubic feet of gas (of which 8,874,510,000 cubic feet was produced from the pool and the remainder purchased) was injected into the reservoir to maintain the pressure. Mainly as a result of the pressure-maintenance program, the total oil production at the end of November 1937 was 13,629,000 barrels—nearly 200 percent of the normal expected ultimate recovery; by the time the field is ready for abandonment ultimate recovery is expected to be about 300 percent of that normally produced from similar pools where pressure maintenance is not practiced.

*Optimum rate of withdrawal of oil from pools.*—Engineers generally agree that the maximum rate at which a pool can be produced efficiently and economically can be determined. Solely from the engineering viewpoint the optimum rate of withdrawal of oil is that which will result in production of a unit quantity of oil with minimum decrease in reservoir pressure. If the pool is densely spaced such rate of withdrawal may not be economical, in that the production of oil per well will be so small that the wells cannot be operated profitably. If the pool has been underdeveloped in the sense that the wells have been spaced too far apart, excessive rates of production from the individual wells may be necessary to produce the oil from the reservoir at the optimum rate. However, at excessive rates of production from the individual wells the tendency of gas to bypass the oil in the reservoir sands is increased, edgewater tends to encroach irregularly into the oil-bearing part of the reservoir, and bottom water where present cones upward around the wells, floods the oil sands, and prevents oil from entering the wells.

If the wells in a pool in which there is an active water drive were to be operated to complete exhaustion and not abandoned when it became unprofitable to operate them any longer, to operate them at excessive rates during their producing life might not affect the ultimate recovery of oil from the pool. Bypassing of gas to a well and premature drawing of water into a well would be purely local problems; they would affect only the well damaged by the gas and water; the pool as a whole would not suffer, as all the recoverable oil would be produced eventually, regardless of the manner of operating the wells. However, long before the last barrel of recoverable oil entered a well the wells in the field would produce almost all water with only a little oil; and, at the present price of oil, the wells would be unprofitable to produce. The cost of lifting water from a well is the same as that of lifting oil. Only the oil, however, has any monetary value at the wellhead; and if enough oil is not produced to pay the cost of operating the wells, pumping operations become unprofitable and usually are terminated. Furthermore, disposal of the water produced with oil usually is expensive. As discussed earlier in this report, disposal of oil-field waters (brines) in creeks and rivers or in a manner that leads to contamination of domestic sources of water supply is prohibited by law in many areas.

Thus, oil wells usually are abandoned long before all the recoverable oil is withdrawn from the reservoir, and the eventual ultimate recovery therefore hinges on the quantity of oil recovered to the time when it is no longer profitable to pump the wells. For that reason, how close or far apart the wells in a pool are drilled and whether they are permitted to flow at high or low rates are matters of great importance.

By conserving the reservoir energy during the early life of a pool the ultimate recovery from a reservoir is increased because such conservation prolongs the life of wells. By conserving reservoir energy early in the life of a pool bypassing of gas is reduced, and the more orderly expansion of the gas causes more of the oil to move through the sands to the wells; the edgewater line advances uniformly up the structure into the oil-bearing sands, and bodies of oil-filled sands are not surrounded by water and the trapped oil retarded in its movement toward the wells until long after they have been abandoned as unprofitable producers. Thus, through efficient operation, the profitable life of

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[30] Bennett, E. O., Work cited in footnote 29, pp. 124–125.

wells is extended, and by such extension the ultimate recovery of oil from reservoirs is increased.

*Efficient rates of oil withdrawn in some Texas fields.*—Optimum or efficient rates of withdrawal vary with size of the pool, thickness of producing formations, kind of oil, quantity of gas in solution in the oil, and many other factors. In 1934, John R. Suman, vice president, Humble Oil & Refining Co., in an address before the American Petroleum Institute, Pittsburgh, Pa.,[31] presented data on the efficient rates of production of a number of fields in Texas.

The writers of this report have taken Suman's published data, and the average net thickness of the producing formations obtained from other sources,[32] to form table 17. Although the fields listed in the table are not exactly comparable, and more recent studies have changed to some extent the estimated efficient rate of production in some of the fields, yet the computed efficient rates of oil production in barrels per day per well per foot of producing formation and per acre-foot are indicative, within approximate limits of accuracy, of the quantity of oil that may be produced at rates considered efficient.

TABLE 17.—*Efficient rates of oil production for a number of fields in Texas*[1]

| Field | Efficient rate of oil production, total for field, bbl. per day | Efficient rate of oil production, bbl. per day | | | |
|---|---|---|---|---|---|
| | | Per well | Per well per foot of producing formation | Per acre | Per acre-foot |
| Yates | 62, 500 | 132 | 1. 32 | 3. 56 | 0. 036 |
| Thompsons | 20, 000 | 121 | 1. 44 | 6. 73 | . 080 |
| Sugarland | 12, 000 | 148 | 2. 47 | 10. 58 | . 176 |
| Van | 47, 500 | 90 | . 33 | 12. 80 | . 048 |
| Conroe | 75, 000 | 77 | 1. 10 | 4. 30 | . 614 |
| East Texas | 375, 000 | 17 | . 48 | 3. 33 | . 095 |

[1] Compiled from data by John R. Suman, Oil and Gas Jour., May 31, 1934, p. 68.

Complete histories of oil fields in which production is restricted to rates approaching maximum efficiency are not yet available, but in no major field that has been operated at or near its most efficient rate has it been necessary to resort to pumping the majority of wells. Suman[33] gives tabular data to show that ultimate costs, in dollars per barrel, of oil from fields producing at efficient rates are much less than costs of production in older fields where less-efficient methods have been used. In addition to the saving in production costs, probably one-third to one-half[34] more oil is obtained from fields operated at restricted rates as compared to what might have been recovered if no restriction had been placed on the rates of production.

### RECENT DEVELOPMENTS IN WATER-FLOODING TO INCREASE OIL RECOVERIES

The application of artificial water flooding for increasing the recovery of oil from partly depleted sands has until recently been confined almost entirely to the Bradford field in Pennsylvania and New York. Water flooding was legalized in certain sands in Pennsylvania by legislative action in 1921,[35] and although the method was carried on rather haphazardly for a number of years and no serious effort was made to control the rate and direction of the movement of the water introduced into wells set aside for the purpose, operators soon learned that an orderly system of flooding is necessary to obtain full

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[31] Suman, John R., Correct Well Spacing, Use of Modern Method Will Insure All Operators Equal Recovery. (Author's title, The Well Spacing Problem: Low Density Increases Ultimate Recovery): Oil and Gas Jour., May 31, 1934, p. 68.

[32] Trans. Am. Inst. Min. and Met. Eng., vol. 132, Petroleum Development and Production, 1939, New York.

[33] Suman, John R., work cited in footnote 31, p. 68.

[34] Many engineers believe that proper restriction of production rates doubles and sometimes triples the recovery of oil from the fields over what it would have been if there had been no restriction on production rates.

[35] Pennsylvania Stats., 1920, 16268a–3; acts 1921, p. 912, 3 (amended, 1929, p. 821).

advantage of the water drive. Sand conditions in the Bradford field were especially favorable for water flooding; the oil-bearing sands are at a shallow depth; water suitable for injection was plentiful; and ordinary flowing and pumping had extracted only about 14 to 25 percent of the original oil in the sands.

Different arrangements of water-intake and oil-producing wells were tried in the Bradford field—the circle flood with one water-intake well surrounded by producing oil wells; the line flood—a line of equally spaced water-intake wells staggered between two rows of equally spaced oil-producing wells; the five spot—one oil well equidistant from four water-intake wells arranged in a rectangular pattern; and the seven-spot—one oil well surrounded by six water-intake wells. The most recent practice generally considers the five-spot arrangement best adapted to intensive development.

Efficiently operated water-flooding projects in the Bradford field are recovering about 40 percent of the oil remaining in the sands after ordinary methods of production no longer could be practiced with profit, and it was estimated in 1934 that at this time a reserve of 600,000,000 barrels of recoverable oil had been established that never would have been recovered by conventional methods of production.[36]

Despite the success of water flooding in certain sands in Pennsylvania and New York oil producers in other States hesitated for many years to suggest the intentional admittance of water to an oil sand and took no steps to attempt to make such procedure legal. Today, however, water flooding is approved by the industry, and although its application has not been widespread the water flooding method now is being used legally in various parts of Oklahoma and Kansas and in one or two pools in Texas.

According to George H. Fancher, department of petroleum engineering, University of Texas, and Kenneth B. Barnes, department of petroleum production, University of Tulsa, the Bartlesville sand in eastern Kansas and northeastern Oklahoma probably contains the largest recoverable oil reserve in the Mid-Continent, as measured by the potentialities of water flooding.[37] The productive area of the sands suitable for water flooding in eastern Kansas and northeastern Oklahoma is estimated by them to be approximately 1,400,000 acres and to contain a reserve of 3,000,000,000 barrels of oil recoverable by water flooding.

Despite difficulties attending water-flooding endeavors in the Mid-Continent and the fact that considerable experimentation was and in some respects still is necessary to develop methods suited to the peculiar conditions found in that area, the physical success of controlled water flooding is assured, and economic success is anticipated. In the 10 months following initiation of water flooding in one area of the Bartlesville sand, oil production increased from 275 to 2,480 barrels per month; oil production for a 100-acre property producing from the Peru sand in Kansas increased from 4,421 to 40,763 barrels per year in 8 years; and on another property in Kansas where water flooding was begun about 1911 oil production in 1918 from 300 acres was at the rate of 60 barrels per day, and by 1935 had increased to 180 barrels as a result of controlled water flooding.[38]

From the favorable results in increased oil recoveries obtained so far on a limited number of water-flooding projects in the Mid-Continent, secondary oil recovery by controlled water drive in that area seems to have great possibilities that will become increasingly evident as the physical difficulties attending this type of recovery method are overcome. It seems, therefore, from the standpoint of conservation of oil, that when economic conditions warrant, water flooding in certain areas of the Mid-Continent can be depended on to supply increasingly greater quantities of oil that ordinary production methods cannot recover.

## PRORATION OF OIL PRODUCTION

Proration in the oil industry is a planned production measure designed to prevent waste of an irreproducible natural resource, insure ratable takings, and balance supply and demand. More specifically, proration, according to H. M.

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[36] Miller, H. C., and Lindsly, Ben E., Work cited in footnote 23, (p. 380), p. 1210.

[37] Fancher, George H., and Barnes, Kenneth B., Water-Flooding in the Mid-Continent: Am. Inst. Min. and Met. Eng., Petroleum Development and Technology, 1936, p. 162.

[38] Data from report by Fancher and Barnes, Work cited in footnote 37, pp. 170–171.

Stalcup,[39] vice president in charge of production, Skelly Oil Co., is a plan designed—

> (*a*) To limit total production to economic consumptive demand, thus eliminating the uneconomic and wasteful necessity of above-ground storage.
>
> (*b*) To limit the individual lease or well to its proper and equitable share in the over-all production from the pool, and
>
> (*c*) To obtain a greater ultimate recovery of oil through proper use of reservoir energy, both gas and water drive, and allow oil production to be taken from the various leases in a pool at such comparative rates that underground energy would be fully utilized and waste prevented.

In most of the major oil-producing States proration is administered by State regulatory bodies through the power of the States under authority of their conservation laws to restrict the flow of oil and gas from the individual wells. In California, however, proration is voluntary; and in Illinois proration is neither mandatory nor voluntary. In general, throughout the oil-producing States, most progressive producers favor proration, and the Federal Government has accorded its cooperation by providing (through the Bureau of Mines) advisory quotas, agreeing to unit plans of operation of Federal lands, circumscribing imports, checking movements of "hot oil" (oil produced in violation of State laws or regulations) in interstate commerce, and ratifying an Interstate Oil Compact.

According to Ely:[40]

"The present mechanism of control follows, with important exceptions, the pattern outlined by the Federal Oil Conservation Board, and particularly by its chairman, Dr. Ray Lyman Wilbur, in a series of reports from 1929 to 1933.[41] It (the present mechanism of control) has four phases: First, the determination of the probable demand, and the allocation among areas of the country of the production required to meet certain components of that demand. This is done through a Federal fact-finding service, centered in the Bureau of Mines. Second, the cooperation of the producing States through an interstate compact. Third, Federal regulation of interstate and foreign commerce in petroleum and its products. Fourth, the enforcement of these interrelated production quotas by the various States, each acting through its own regulatory body. In each phase there is a measure of cooperation between State and Federal Governments and industry."

Proration as it is known today had its inception in the Seminole area, Oklahoma, in 1926, when it became necessary to take steps to balance supply with demand. At first, proration was effected through voluntary action between the operators in the area. This voluntary action, however, was not entirely successful in stemming the rising tide of production and controlling it to market demand. Therefore, on August 9, 1927, the Corporation Commission of the State of Oklahoma took matters into its own hands and issued order 3944, limiting daily oil production in the Greater Seminole area to 450,000 barrels and providing that each lease covered by the plan might produce the same proportion of the allowable production that the total production of the lease bore to the total potential production of the field. Since that time, all newly discovered major fields with certain exceptions, notably the recently discovered fields in Illinois, and many smaller pools in the United States, have been developed under proration agreements.

Again quoting Ely:[42]

"On February 16, 1935, the States of Texas, Oklahoma, California, Kansas, New Mexico, Colorado, and Illinois entered into an oil conservation compact obligating each State to enact and enforce conservation laws, and to cooperate through an interstate commission which has 'power to recommend the coordination of the exercise of the police powers of the several States within their several jurisdictions to promote the maximum ultimate recovery from the petroleum reserves of said States, and to recommend measures for the maximum ultimate recovery of oil and gas' * * *. The Compact was ratified by all but California."

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[39] Stalcup, H. M., What the Oil Industry Is Doing About Conservation: Oil and Gas Jour., May 19, 1938, p. 50.

[40] Ely, Northcutt, The Conservation of Oil: Harvard Law Review, vol. LI, no. 7, p. 1213, The Harvard Law Review Association, Cambridge, 1938.

[41] See 1 and 5 Rep. Fed. Oil. Cons. Bd. (1926 and 1931); Rep. Sec'y Int. (1931) 24; statement of Secretary Wilbur to a committee of the American Petroleum Institute, April 12, 1929, quoted in Ely, Oil Conservation Through Interstate Agreement (1933) 18.

[42] Ely, Northcutt, Work cited in footnote 40, p. 1215.

On June 19, 1939, Congress was asked to approve a 2-year extension of the Interstate Oil Compact, which was due to expire September 1 and which was participated in by Texas, Oklahoma, Kansas, New Mexico, Colorado, and Illinois. All these States except Illinois had authorized renewal of the compact, and Michigan had been enlisted as a new member.[43]

On July 19, 1939, Gov. Culbert L. Olson of California signed the Atkinson bill, modeled after the New Mexico conservation law, which provides for substitution of State proration for voluntary curtailment by producers. The act was to have become effective on September 19, 1939, but almost immediately after its enactment it was threatened with a referendum sponsored by some independent operators, and before it could become effective enough signatures on the referendum petitions had been obtained to assure placing the question before the people of the State on the ballot to be voted on in November 1939. The bill was specifically endorsed by President Roosevelt, who sent a telegram to Governor Olson urging its passage, to enable the State to go along with the national administration in its oil-conservation program. Proponents assert that State control of oil production was needed because a small number of operators in the industry made voluntary proration ineffective. On the other hand, opponents of the bill charge that it was supported by large companies, who sought to avoid possible antimonopoly prosecution under established voluntary curtailment.

Overproduction in Michigan has been a troublesome factor during the past few years, and voluntary proration was not entirely successful. Curtailment of production now, however, has been placed under State proration based on the recently enacted oil-conservation law.[44]

Illinois is the only State with important flush production that remains without State proration. Already the depressed prices of crude oil in Illinois have affected old as well as new fields of the State and have caused abandonment of many stripper wells in the State. Hence, the owners of these wells and some operators in new fields are exerting pressure in favor of State proration.[45]

### OPINIONS ON PRORATION PROCEDURES TO AFFECT CONSERVATION OF PETROLEUM

In a paper before the annual meeting of the American Institute of Mining and Metallurgical Engineers in New York in February 1939, H. C. Weiss, president, Humble Oil & Refining Co., outlined certain principles of oil conservation and gave analysis of present-day conditions, together with expressions of his personal observation, study, and experience. With this background, Mr. Weiss then submitted for consideration, analysis, and application the following broad policies:[46]

> 1. Our oil reserves should be developed and produced with maximum practical efficiency both from physical and economic viewpoints.
> 2. To attain such maximum efficiency it is essential that the total production of the United States be restricted to market demand requirements.
> 3. To attain such maximum of efficiency, localized market demand should not be the sole criterion by which to restrict local production.
> 4. Each State and each area or field within each State should produce in such a manner as to coordinate the requirements of market demand and physical efficiency. This would be furthered by accepting the principle that each State participate in supplying the total market requirements largely on the bases of reserves, with appropriate prior recognition to stripper production.
> 5. Remove the incentive for unnecessary and unprofitable drilling. Subject to the requirements of minimum physical waste, this calls for the acceptance as an incident of proration of the general principle that each operator seek to produce only the recoverable oil from his land.

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[43] Public Res. No. 31, 76th Cong., consenting to an interstate oil compact to conserve oil and gas was approved by Congress July 20, 1939.

[44] Michigan Act No. 61, P. A. 1939.

[45] By Sept. 5, 1939, operators representing 97 percent of the State's oil production signed petitions asking the Governor of Illinois to call a special session of the State legislature to consider oil-conservation measures. See Oil and Gas Jour., Sept. 7, 1939, p. 37.

[46] Weiss, H. C., Some Current Problems in Oil Conservation: Oil and Gas Jour., Feb. 23, 1939, p. 46.

According to Col. E. O. Thompson, member, Railroad Commission of Texas, the experience attained in the East Texas field suggests the answers to the whole conservation problem.[47]

He stated in part: "If the optimum rate of flow could * * * be determined for every oil pool in the United States and the production held to that, there might, as between the States, be no proration problem. It is quite possible that if all the oil in the United States were produced without waste the total production would not exceed the needs of the market. The only proration would then be between the producers within a field.

"The entire industry understands the disasters that will follow if proration should be entirely abandoned.

"The first trouble is in the arrangement between the States * * * not all of the producing States are members of the interstate oil compact. The members use as a basis for allocation the market forecasts of the Bureau of Mines. The bureau has done a magnificant job in the over-all forecast.

"The figure which the bureau uses in determining the market demand of a State is the past movement of the crude from that State. When a State, in a stern effort to bring stability, cuts its own permissible allowable, the figures of the bureau soon reflect that cut, and the open areas gain in their estimated requirements. The bureau, of course, takes the facts as it finds them.

"A fairer method would be to base the allowables on the developed reserves, conditioned, of course, upon their ability to produce without waste. If this were done every State would produce in the proportion that its reserves bore to the total reserves of the nation. If a State had 20 percent of the reserves it would produce 20 percent of the needed daily allowable. As a State built up reserves it would gradually build up markets. As a State's reserves were depleted its allowable would drop. This would more nearly approximate true competitive conditions which would be in effect were proration not in vogue. Texas today has 53 percent of the reserves and is producing 38 percent of the market."

According to Joseph E. Pogue, vice president, Chase National Bank of the City of New York, in addressing fellow members of the American Institute of Mining and Metallurgical Engineers, in New York, in February 1938:[48] "Proration has now evolved to the point where it clearly rests upon two thoroughly established principles—conservation and equity; and involves three procedures—curtailment of flow, ratable takings, and an adjustment of restricted flow to balance the measured requirements of the market. The system is administered by means of a quota system by which it is sought to bring into accord the requirements of waste prevention and market demand, without violation of the dictates of equity. In theory no pool is permitted to produce more than its market demand, it being recognized that output in excess of market demand leads to storage, physical waste, and economic instability; whereas restriction to market demand or to the most efficient rate, whichever is lower, results in effective conservation and economic advantage. It is difficult to differentiate accurately between the stabilizing effects derived from curtailment to efficient rates and those superimposed by the functioning of market-demand quotas, because any degree of restriction upon output necessitates operations under some measure of back pressure. The casual view that proration in essence is purely a stabilization measure is in error, for a substantial degree of the stabilization observable in practice is the automatic resultant of restricted flow and ratable takings instituted on the basis of conservation. It is impossible, for example, to operate an oil pool under back pressure without leveling out the production curve and thereby flattening the cost curve; in consequence, a smoothing effect is transmitted to price. Under the practice of proration, therefore, entirely aside from the application of market-demand quotas, a significant byproduct of economic stability is inevitable.

"In the operation of any economic system, of course, supply and demand must balance. Accordingly, if oil pools are to be restricted in the interest of conservation, the aggregate curtailment must conform to the dictates of demand, if consuming power is not to be regulated. Accordingly, the employment of market-demand quotas is a practical expedient to make the system workable, for existing

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[47] Thompson, E. O., An Administrator's Views on Proration: Oil and Gas Jour., Feb. 23, 1939, p. 47.

[48] Pogue, Joseph E., A Design for More Effective Proration: Trans. Am. Inst. Min. and Met. Eng., Petroleum Development and Technology, vol. 132, 1939, p. 206.

demand does not coincide in all its ramifications with the various elements of supply at their respective optimum rates, and hence an additional element of equilibration is necessary. Nevertheless the need for this additional element is probably not as great as generally believed, for judging from preliminary studies, the difference between the aggregate optimum production rate of our oil fields and market demand is not substantial; consequently proration can be directed so as to approach a plane of natural equilibrium between demand and a supply restricted according to engineering principles. At this stage, dependence upon market-demand quotas will be greatly lessened, if not entirely removed. This conclusion deserves the greatest emphasis, for the tendency in the industry is to overlook the advanced degree of evolution and hence to miss the point of great significance in the economics of the petroleum industry.

"Although proration appears to have its logical goal almost within its grasp, it is not assured that this instrumentality will be permitted to follow its natural courses to such an outcome. If the potentialities of proration were clearly envisaged by all concerned, this danger would not exist; but there are many who look upon proration solely as a stabilization device that is faulty because it fails to deliver all that is hoped of it on this score and hence desire to implement it with additional controls designed to achieve these ends. Such a course of development, in pursuit of transient and illusive gains, will lead to a condition of progressive economic regimentation that will destroy the vigor and flexibility of the industry, to the detriment of its profitability as an industrial enterprise and its serviceability to the public. On the other hand, the steps needed for the successful passage of proration into a perfected conservation measure, carrying with it a high degree of derived economic stabilization at the expense of minimum interference with competitive processes, are not complicated nor beyond reasonably early attainment.

"The technique of proration is adequate for the purpose, all the necessary principles have become established, and a successful outcome waits merely upon a broader cooperation among the oil-producing States and concerted efforts on the part of the regulatory bodies, the Interstate Oil Compact Commission, and the oil operators. Five points are herewith offered for consideration:

"1. The development of the optimum rate concept as a yardstick for restricting the individual oil pool.

"2. The standardization of the application of bottom-hole pressure readings for the effectuation of ratable takings.

"3. The harmonizing of drilling incentives with the requirements of delayed production.

"4. The employment of market-demand quotas to reconcile the interim differences between optimum rates and market requirements.

"5. The preservation of flexible markets to proportionate capital flow to economic requirements and prevent the development of intra-industry pressures."

Although initially intended to correct conditions of overproduction of crude oil, proration is a fundamental conservation measure. Under proration the production of wells is curtailed, and new wells are not permitted to flow "wide open" with consequent wastage of gas and reservoir energy. Operations in prorated fields have demonstrated clearly that reservoir energy is conserved by restricting the rate of flow of oil from wells and that ultimate recoveries of oil from the reservoir are increased and costs of production decreased materially. Engineers have found that the most efficient way to operate an oil pool is to utilize to the utmost the energy in the reservoir resulting from the gas under pressure and from the high-head water that underlies the oil in the majority of pools. Properly conserving the reservoir energy also prolongs the natural flowing life of wells and defers the need for installing and operating pumping equipment until most or all of the recoverable oil has been drawn from the pool. Therefore, operating oil pools at less than their open-flow capacity not only permits more efficient recovery of oil from the existing wells but new wells can be spaced farther apart with a consequent reduction in the cost of developing and operating the pools.

## UNIT OPERATION OF OIL POOLS

Fifteen years ago Henry L. Doherty, president, Henry L. Doherty & Co., publicly suggested a plan by which all operators owning land or leases in an area overlying an oil pool might combine their interests and extract the oil and gas from it as a unit. Unitization of oil pools means merging the interests of individual owners of the oil and gas rights in a pool into a common ownership and designating one operator to develop and produce the properties in a noncompetitive and scientific manner. Man-made boundary lines on the surface of the ground above oil and gas pools are disregarded in unitized areas, and the pools are developed and produced as if the oil and gas rights were owned by one operator. Unitization, by disregarding surface property lines, permits uniform spacing of wells and production of oil from the reservoir at the most efficient rate. Inasmuch as the "rule of capture" has no part in dictating development and producing operations in unitized areas, there are no capital expenditures for drilling and operating unnecessary wells, wider well spacing than otherwise possible can be inaugurated in developing the area, and the pool can be operated according to the dictates of advanced engineering practices.

Although the advantages in increased oil recovery and reduced development and operating costs resulting from unitization of oil pools of diversified ownerships are numerous and great when converted into barrels of additional oil recovered and dollars saved, unit operation, in one form or another, is practiced only in some 185 oil pools in the United States. The tremendous advantages of unitization have been cited by Frank Phillips, chairman, Phillips Petroleum Co., by reference to two of the many pools in which his company is a lease owner and has attempted unitization.[49] According to Phillips:

"In the unit project at Billings, Okla., involving a pool covering hardly more than 1 square mile, scientific development has accomplished a saving of one-half million dollars by eliminating unneeded additional wells and pumping equipment, even though this pool was almost fully developed before unitization was consummated. Proper utilization of reservoir energy also will reduce operating costs by another 1½ million dollars. Ultimate oil recovery will be increased at least 25 percent."

In another area the Phillips Petroleum Co. was unable to convince certain other lease owners in a common pool that all should combine their interests and operate the pool as a unit. There, according to Phillips, "unitization would have eliminated the drilling of 65 deep wells at a cost of $80,000 each. Even after the addition of equipment necessary for injecting gas into the producing horizon to maintain reservoir pressure, the saving in development costs alone would have amounted to $4,500,000. Additional savings in operating and overhead expense, through scientific withdrawal practices and mass-production methods conducted by one, instead of several operators, were estimated to be 12 cents per barrel, or $4,500,000. Unitization, coupled with an effective pressure-maintenance program which it would have permitted, would have recovered 53 million barrels of oil instead of only 38 million barrels, to be obtained under present nonunitized methods."

The majority of executives, engineers, and producers of oil agree that the ideal way to produce an oil field is to restrict the flow from the pool to a rate that results in maximum effective utilization of the reservoir energy. Such operation, however, is impossible in fields where the pools are operated under the "rule of capture"; in consequence the percentage recovery of oil in competitively operated pools is low, development costs are high because more than the optimum number of wells to recover the oil are drilled, and operating costs soar because pumping has to be resorted to early in the life of the pools. On the other hand, by conserving the reservoir energy by restricting the rate of flow of oil from the pool, pumping usually can be deferred until near-exhaustion of the recoverable oil from the reservoir.

### ECONOMICS IN THE DEVELOPMENT AND EXPLOITATION OF THE UNITIZED SOUTH BURBANK FIELD, OKLA.[50]

The South Burbank pool was unitized shortly after the pool was discovered in January 1934. By mutual agreement to communitize their acreage and develop and produce it in a wise, efficient manner, 16 property owners merged their interests and created the South Burbank Unit, comprising 2,720 acres. The percentage participation of each owner was determined by the relation-

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[49] Phillips, Frank, Streamlined Science Needs Horse-Sense Economics: Mines Mag., June 1939, p. 253.

[50] In the preparation of this section on the South Burbank pool, a report, Pressure Maintenance and Unitization—South Burbank Pool, by I. S. Salnikov and M. L. Haider, of the Carter Oil Co., published in Am. Petrol. Inst., Drilling and Production Practice, 1937, pp. 91–100, has been drawn on freely.

ship which the estimated recoverable reserves under his acreage bore to the total estimated recoverable reserves of all the acreage included in the unit.

The Carter Oil Co. was selected to operate the unit, and under its supervision the unit began to function on June 1, 1935. The production practice from initiation of unitization was to operate the wells at a rate commensurate with the most efficient gas production, thus causing a minimum withdrawal of gas from the reservoir. High gas-oil-ratio wells were shut in until the cause of the high rate of gas production could be corrected. This production practice was made possible by unit agreement among the operators, and by a special permit of the Indian Agency of the United States Department of the Interior granting a blanket lease to the 2,720 acres embraced in the unit and abolishing all former internal property lines from the standpoint of royalty.

The major purposes of unitizing the South Burbank pool were to carry out a pressure-maintenance program by returning gas to the formation at a pressure of approximately 1,000 pounds per square inch and to effect economies in the development and exploitation of the pool. Pressure-maintenance aimed to prolong the flowing life of the wells and to increase the ultimate recovery of oil from the pool and wider well spacing than would have been adopted if the pool had not been unitized reduced material inventories, permitted the standardization of equipment, and lowered overhead and labor costs—all indirect benefits to be derived from consolidation of the 16 properties under one management.

Salnikov and Haider[51] have summarized the benefits of the pressure-maintenance program in the South Burbank pool by citing the following accomplishments made possible under the unit operation:

1. Crude-oil production with a minimum dissipation of gas from the reservoir, resulting in conservation of available gas energy.
2. Return of produced gas to the reservoir to maintain pressure and to facilitate drainage.
3. Elimination of gas wastage occasioned by frequent potential tests. The operator's agreement in the South Burbank pool provides for only one potential period and subsequent corrections of potentials by subsurface pressures.
4. Sustained long flowing life of wells and consequent lower production costs per barrel.
5. Increased oil recoveries or yields per acre dependent upon pressure maintenance and preservation of the fluidity of the oil in the reservoir.
6. Low-drilling and development investments effected by wide spacing of the wells.

K. E. Beall, of the Phillips Petroleum Co., in a written discussion of the Salnikov and Haider report,[52] points out that it is impossible yet (1937) to determine definitely whether pressure maintenance in the South Burbank pool will prolong the flowing life of the wells and increase the ultimate recovery of oil from the pool. Economies in development and operation, however, definitely have been accomplished, as there has been a very large saving in development expenses. The saving in drilling and equipping wells has been $4,000,000 to $5,000,000. An additional saving of approximately half that amount has been made in operating costs. Accordingly, with oil production coming from approximately half as many wells as would have been drilled if the pool had not been unitized and the greater proportion of the ultimate production flowing naturally from the wells instead of having to be swabbed and pumped, there has been a saving of 10 to 15 cents a barrel in lease-operating costs. In 1937, 3 years after the pool was discovered, over 98 percent of the production still was flowing naturally.

Although estimates of the increase in ultimate oil recovery in the South Burbank pool resulting from pressure maintenance (made workable by unitization) range from 20 to 60 percent operations have not been carried on long enough to justify an accurate declaration of how much oil will be recovered than would have been produced ultimately if the field had not been unitized. More definitely, however, it is known that injecting the surplus gas produced with the oil into the reservoir—thus preventing its waste—has maintained the fluidity of the reservoir oil in the South Burbank pool. Because of that

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[51] Salnikov, I. S., and Haider, M. L., Work cited in footnote 50, p. 99.
[52] Salnikov, I. S., and Haider, M. L., Work cited in footnote 50, p. 100.

condition, the greater distance the oil has had to move through the sand to reach a producing well has been offset. In other words, pressure maintenance and wide spacing of wells in the end should, at less expense, yield a quantity of oil at least equal to that obtainable if the wells were spaced more closely and formation pressure was not maintained.

To January 1, 1938, when 18,500,000 cubic feet of gas per day—15,000,000 cubic feet by the operator of the unit and 3,500,000 cubic feet by operators of several adjacent outside leases—under pressures up to 900 pounds per square inch was being pumped back into the producing formation in the South Burbank field, a total of 9,900,000,000 cubic feet of gas had been returned to the oil-producing reservoir.[53] To November 1937 reservoir pressures declined 30 pounds per square inch for each 1,000,000 barrels of oil produced, and after the full effect of the injected gas became established reservoir pressures declined only 20 pounds per square inch for each 1,000,000 barrels of oil produced, indicating an increase in oil production of 17,000 barrels per pound drop in reservoir pressure. In addition to the greatly increased ultimate recovery of oil expected for the minimum development and operating expense as a result of the establishment of pressure maintenance early in the life of the field, large quantities of gas would have been wasted if the pressure-maintenance program had not been started during the flush-production life of the field.

### COOPERATIVE DEVELOPMENT PLAN FOR BUENA VISTA HILLS OIL AND GAS FIELD, CALIF.[54]

As early as 1933 the adoption of a plan of cooperative development of the deep production underlying upper near-exhausted sands in the Buena Vista Hills field, Calif., was considered desirable. The area comprises 39,040 acres, of which Naval Petroleum Reserve No. 2 is part and constitutes the major portion of the Federal leases subject to the proposed plan. Of this acreage 24,640 acres (63.1 percent) are owned in fee, 10,800 acres (27.7 percent) are United States Navy fee or leased lands, and 3,600 acres (9.2 percent) are under lease from the United States Department of the Interior.[55]

A cooperative plan of development for the field was drafted in 1935, and several agreements between the lessees of certain operating units of one-quarter section each, where the ownership was divided, were executed early in 1936. On April 30, 1936, the oil and gas supervisor for the State of California, as required by State law, approved the plan-agreement for cooperative development of the Buena Vista Hills field and determined that it was in the interest of the protection of oil and gas from unreasonable waste that the plan agreement be entered into by the signatory parties thereto.

On July 6, 1936, the President of the United States consented to execution of the plan agreement by the Secretary of the Navy, and on July 9, 1936, the agreement was executed on behalf of the United States by the Secretaries of the Navy and of the Interior, thus completing adoption of the plan by all interested parties.

The United States controls approximately 37 percent of the area subject to the cooperative development plan applying to the newly discovered lower sands in the Buena Vista Hills field. Of this area, 3 percent is owned by the United States Navy and not leased, and 34 percent is under lease to various operators. The leases from the Navy Department and from the United States Department of the Interior were granted about 1922 for a period of 20 years, with certain provisions for renewal at successive 10-year periods.

Statutory authority contained in the acts of Congress approved March 4, 1931, and August 21, 1935, amending the Oil and Gas Leasing Act of February 25,

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[53] Bennett, E. O., Pressure Maintenance: Am. Petrol. Inst., Development and Production Practice, 1938, p. 122.

[54] In the preparation of this section, a report entitled "Cooperative Development Plan for Buena Vista Hills Oil and Gas Fields, Kern County, Calif.", by C. M. Nickerson, senior petroleum engineer, Office of Inspector, Naval Petroleum Reserves in California, published in Trans. Am. Inst. Min. and Met. Eng. Petroleum Development and Technology, 1937, vol. 123, pp. 183–194, has been drawn on freely.

[55] To modify certain supplementary agreements with royalty owners, excepting from this group the United States as lessor, which agreements conflict with the provisions of the cooperative development plan, it was necessary to obtain the consent of the royalty owners to the execution of the plan by the operators and to agree that the development of the area in the manner set forth in the plan shall be considered as full performance of all obligations for development and operations of certain parcels formerly required under the original agreement with the royalty owners. These consents of royalty owners were obtained in practically all instances, and the modification of the original royalty owner agreements eliminates any conflict between lease requirements, royalty owner agreements, intracompany desires and needs, and curtailment of production.

1920, permitted the Secretaries of the Navy and Interior to enter into unit plans involving cooperative development of an oil- and gas-bearing structure. These acts permitted the Secretaries to modify the drilling and producing requirements, terms, and royalty provisions of the leases theretofore issued under the act of February 25, 1920.[56]

The agreement between the United States and its lessees provides that the Operating Regulations approved July 1, 1926, as amended prior to July 1, 1935, shall be effective for these leases in lieu of all other regulations promulgated by the Government. The Secretary of the Department having jurisdiction over the lands of the United States is vested with the authority to control the rate of development and production from these lands in order that the area covered by the cooperative development plan in the Buena Vista Hills may enjoy its fair and proper share of the allowable production for the State of California under any system of agreement generally recognized by the operators in that field, or by any system authorized by law.

The agreement provides that the United States will not lease or operate any lands it may own, except subject to the terms and provisions of the plan-agreement. In turn, the lessees of the United States agree to protect the Government lands from loss of royalty through drainage within and without the exterior boundaries of the area by drilling and producing the necessary offset wells or by paying compensatory royalty in lieu thereof.

The plan-agreement with the United States provides that if the agreement is terminated with respect to any Government lease the original terms and conditions, including rents and royalties, of the lease shall become effective. If termination occurs before the date of expiration of the lease it shall be renewed as provided in section 17 of the act of February 25, 1920.

Provision also is made in the plan-agreement to amplify, change, or modify the terms of the agreement with the written consent of the operators of 80 percent of the area of the leases included in the plan-agreement, with the written approval of the respective Secretaries.

Unlike unit plans, the cooperative plan for the development of the Buena Vista Hills permits each operator to drill and operate his own wells. There are 27 operators within the area; 26 (controlling 99.5 percent of the acreage) have signed the plan-agreement.

Under the cooperative plan of development of the deeper zones, operating units of 160 acres each were established. The first wells to be drilled under the plan are called "primary wells" and are in the center of each 160 acres (quarter section). The plan contemplates drilling first of the primary wells that will give a spacing of ½ mile between the first wells. According to Nickerson[57] such wide spacing in an even pattern over the productive portions of the structure automatically eliminates unnecessary competition, virtually all drainage considerations, and other troublesome factors involved in completion of the early wells in a field if placed in the corner of the section or lease.

After the primary wells are completed on an operating unit of 160 acres the "secondary wells" may be drilled due north and south, or due east and west, of the primary wells. Thus, the only offset well required by the owners of the adjacent operating units will be one secondary well on their own unit, instead of three offsets, as would be required if a well were completed in the corner of the section or lease.

After all primary and secondary wells are completed the operator may proceed with the drilling of the "tertiary wells" in the four corners of the operating unit. These wells are to be 440 feet from the quarter-section lines, with 880 feet between the wells. Such spacing gives a theoretical drainage area of 17.8 acres per well.[58]

If primary well locations on units near the edge of the field are found unproductive of oil if drilled the operator may select a secondary location in lieu of the primary location, provided operators of 80 percent of the acreage agree that the primary location is outside the productive limits of the field. By the same procedure, if all secondary locations of an operating unit are considered unproductive a tertiary location may be selected for the first well. Further-

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[56] Under the plan-agreement all leases from the United States were extended for the life of the field, providing that the lands under lease continue to be subject to the plan. Also, new royalty scales for oil, gas, and gasoline produced were adopted which in some cases were lower and in others higher than those for the upper producing sands.

[57] Nickerson, C. M., Work cited in footnote 54, p. 187.

[58] By agreement of the signatory parties holding 80 percent of the acreage the spacing program may be modified if subsequent developments show that closer spacing is necessary to produce the recoverable oil from the reservoir sands.

more, an operator may drill any and all wells on the exterior boundaries of the pool that may be necessary to prevent drainage of his unit by operations on lands not subject to the cooperative plan. No operator, however is obligated under the cooperative plan to drill any well or wells within the pool. Terms of the several leases and good business judgment are considered adequate to govern drilling of wells on each operating unit to protect the interests involved.

The drilling program applies to each productive zone discovered within the limits of the pool. If two separate and distinct zones are discovered each operating unit may have 18 wells drilled thereon, unless further agreements are made to permit deepening certain of the first nine wells, or other equitable procedure adopted.

In order that no operating unit may be disproportionately drained of its oil and gas by operations on adjacent operating units the plan provides (by agreement of operators holding 80 percent of the acreage within the pool) for adoption of uniform producing practices intended to recover the maximum quantity of oil and gas ultimately and to prevent an operator from operating his wells with excessive gas-oil ratios, or at such a rate that one operator may recover more than his fair share of the oil and gas.

In considering that 160 acres is the smallest practical operating unit provision had to be made in the cooperative-development plan to include a dozen or more quarter sections of land where the ownership of the oil and gas rights was divided. Accordingly, the plan provides that where the ownerships are divided and before any wells are drilled, each of these quarter sections will be unitized. The unit plans for operating units of one-quarter section in area provide that one of the two owners of adjacent quarter sections be the Operator of all line wells drilled on the common property line. The second party is called the Associate, and the wells drilled on the common property line are called Joint Wells. Where no wells fall on the common property line one company is appointed the Operator to drill and operate all of the wells in the unit. With this exception and for other than Joint Wells on the common property line, each operator may drill and produce his own wells on the unit. Considerations embodied in the unit plans provide also for the distribution of drilling expenses and operating costs, allocation of oil and gas produced, method of computing and allocating Government oil royalties, and such other requirements as will permit equitable operation of the unit plan to both parties concerned.

Protection against drainage of oil by operators who failed to join the cooperative operating plan for the Buena Vista Hills oil and gas field is provided for in the agreement by permitting any operator to drill such wells as may be necessary at any time and in any location in order to prevent drainage of the operating unit which he controls by operations on lands adjacent thereto but not subject to requirements of the cooperative plan.

The cooperative-development plan (by consent of the operators of 80 percent of the area subject to the plan) provides also that restrictions may be placed on the quantity and rate of production of oil and gas from lands within the area, and if engineering practices or economic conditions warrant the provisions of the plan may be changed.

Although the cooperative development plan for the Buena Vista Hills oil and gas field has been in effect for only about 3 years, according to Nickerson,[59] elimination of unnecessary competition and fostering of cooperative effort by the plan indicate that the deeper zones in this field probably will be developed in the most economical manner and that duplication of facilities will be kept at a minimum.

### UNITIZATION OF THE FULLY DEVELOPED AND PARTLY DEPLETED SALT CREEK FIELD, WYO.

The Salt Creek field, Wyoming, was discovered in 1908, and to January 1, 1939, had produced 283,021,000 barrels of oil.[60] It is the largest oil field in the Rocky Mountain area, and its Second Wall Creek sand covers an area of 21,450 acres. The field has been fully developed by drilling 1,998 wells, of which approximately 1,300 still were producing oil from the several sands during midsummer of 1939. Nearly all wells in the field are being pumped, and the average production per well from the principal producing sand (Second Wall Creek) was approximately 6½ barrels of oil per day in 1938. Typical wells in the field produce 1 to 80 or 100 barrels of oil per day, but comparatively few of the larger wells remain.

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[59] Nickerson, C. M., Work cited in footnote 54, p. 194.
[60] Oil and Gas Jour., Aug. 31, 1939, p. 14.

Development of the field since March 1921, at the time an agreement to prorate the production of the field was entered into by the operators, has been on a unit or near-unit basis. Approximately one-half the acreage of the Second Wall Creek sand and all of the productive area of the First Wall Creek, Lakota, and Third Sundance sands were developed by one operator under contract with six companies. Nearly 40 companies operate the remaining 9,600 acres of the Second Wall Creek sand.

Unit development of a large part of the Salt Creek field eliminated need for drilling at least 500 wells at a cost of $11,650,000.[61] In addition, inestimable savings resulted from not having to produce the reservoir oil until needed; wastage of gas was reduced by avoiding high-peak production; costly surface storage was eliminated; and there was no necessity for providing additional pipe-line facilities to transport the large quantity of oil that would have been produced for a short period if development of the field had been on a competitive basis. Furthermore, the estimated saving of nearly 12 million dollars in development cost does not include any additional revenues resulting from the increased ultimate recovery of oil as a result of unit operation.

For a number of years oil-company engineers have been working on a plan for unitizing operations on approximately 15,300 acres in the Salt Creek field to arrest the rate of decline of oil production and to increase the quantity of oil to be recovered ultimately. Over 90 percent of the owners of leases, working interests, and royalty, including Federal and State land, eventually agreed to the terms and conditions proposed for unitizing the field. On August 28, 1939, after the State of Wyoming agreed to permit its 640 acres in the center of the field to become part of the unit, Harry Slattery, Acting Secretary of the Interior, signed approval of operation of the Salt Creek field as a single unit, except for a few tracts around the outer rim. Operations under the new plan were scheduled to begin on September 1, 1939.

Utilization of the Salt Creek field is a new departure in that never before has an attempt been made to unitize such a large field with so many diversified interests after it had been fully developed. According to the unit-plan agreement, the Midwest Oil Co. and the Mountain Producers Corporation will operate the unit jointly, and the Stanolind Oil & Gas Co. will perform the field work on a long-time contract. Extensive plans are being made to increase the effectiveness and range of the present application of the gas drive and other secondary oil-recovery methods. Other changes in operating methods also are contemplated, all of which should increase the quantity of oil recovered ultimately from the field and reduce the unit cost of production.

### SUCCESSFUL UNITIZATION REQUIRES 100 PERCENT PARTICIPATION

The advantages to be derived through unitization of oil pools are so great it seems inconceivable that more pools in the United States are not unitized and operated as though a single owner controlled the oil and gas rights to the reservoir. Obviously, one operator controlling an entire pool has no incentive to drill more than the number of wells necessary to bring the recoverable oil to the surface of the ground, nor has he any desire to increase the cost of producing the oil by unnecessary duplication of effort and equipment. Yet, when a number of operators develop a pool under competitive methods, each tends to try to get not only his fair share of the reservoir oil but as much more as he can produce—usually with little regard for costs or the efficiency of recovery of oil from the pools.

Theoretically, under unit operation, all participants receive their equitable share of the reservoir's oil and gas at the minimum cost for development and production. The forming of a new unit is a give-and-take proposition, and, although all participants rarely are entirely satisfied, participation in almost every instance will bring greater profits to all than could be secured by operating the properties separately.

The greatest handicap to the unitization of oil pools is the barrier to participation caused by "holdout" operators, landowners, and royalty interests who for one reason or another refuse to join in the unit plan. To be effective, unitization must have 100 percent participation of all interests; otherwise those who do partake start out under a handicap that seldom can be overcome.

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[61] Wood, F. E., Unitization in Rocky Mountain Region: Am. Inst. Min. and Met. Eng., Petroleum Development and Technology, 1930, pp. 48–51.

Recent events show that the "unit" plan of operation of the Kettleman Hills (North Dome) field, Calif., which went into effect in 1931, with part of the acreage of the field not unitized, in the practical sense has not been successful in several respects. It is the opinion of R. E. Collom, vice president, Continental Oil Co., and C. P. Watson, vice president, Seaboard Oil Corporation, as expressed publicly in 1936,[62] that the North Dome of Kettleman Hills is being developed competitively and wastefully in spite of the efforts of the Kettleman North Dome Association.[63] Less than 5 percent of the participating acreage of Kettleman Hills has set the pace for development and has dictated the internal allocation of oil production.[64] Competitive drilling was not eliminated by so-called unitization of the field, oil that would have been produced under a completely coordinated plan of development is being left in the sands, and the gas is being produced not to recover the maximum quantity of hydrocarbons but in a manner that will maintain a saturated outlet to the gas companies. Furthermore, there is no pressure-maintenance program in the North Dome of the Kettleman Hills oil field, and pressure "sinks" have been allowed to form in the areas of greatest oil and gas withdrawal by operators whose lands were not included in the unit plan. As a result of the decrease of reservoir pressure in those areas, edgewater has encroached into the oil-bearing part of the reservoir, and on September 1, 1936, out of a total of 183 producing wells, the production of 69 wells was 10 percent or more water.

Reservoir pressure in the competitively drilled areas has been reduced to less than 50 percent of the original pressure, and the reduction of pressure is spreading to wells 3 to 6 miles distant. According to best engineering thought, loss of pressure in reservoirs due to rapid withdrawal of gas affects the quantity of oil to be recovered ultimately by robbing the oil of its motivating force and increasing the viscosity of the oil and its resistance to flow through the sands toward wells.

According to R. C. Patterson, supervisor, Geological Survey, Los Angeles, Calif., the so-called outside operators controlling 4 percent of the productive acreage and not parties to the untization agreement have recovered (1938) 19 percent of the oil produced from the field.[65] These operators have produced oil and gas at rates in excess of the association and Standard Oil Co. and by so doing have caused the adjoining lands to be depleted of oil and gas at excessive rates. In other words, operations on the so-called outside properties was in accordance with the "rule of capture" rather than on the principle of conservation and optimum ultimate recovery.

The foregoing brief discussion of handicaps that attend the absence of 100-percent participation in a unit-development plan should not be taken to infer that the unit plan for development of the North Dome of Kettleman Hills has been a failure. Although the entire field has not been developed in an orderly manner as a result of nonparticipation in the plan by the owners of less than 5 percent of the acreage of the field, certain benefits have accrued to the participating operators, the Government, and the public that would not have materialized if the development of the field had been on a 100-percent competitive basis.

The experience at Kettleman Hills has shown that the efforts of the industry to overcome the pitfalls resulting from competitive operation of oil pools can be defeated by a very small minority of operators and owners of oil and gas rights. What then can be done to compel the recalcitrant fee landowners owning, as in the Kettleman Hills, less than 5 percent of the acreage to join with

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[62] Collom, R. E., and Watson, C. P., Review of Developments at Kettleman Hills: Am. Inst. Min. and Met. Eng., Petroleum Development and Technology, 1937, pp. 195–213.

[63] The Kettleman North Dome Association is composed of the owners of 8,210 acres, or 49.7 percent of the 16,510 acres of participating oil and gas lands in the North Dome of Kettleman Hills. Fee acreage not included in the Association equaled 540 acres or about 3.3 percent of the participating acreage. The Standard Oil Co. of California, which did not enter the association, owns 7,760 acres, or 47.0 percent of oil and gas-bearing structure. It did, however, agree that its fee holdings be operated as one unit and the association's holdings be operated as another, and that development and operation of the two units be in accordance with an agreement between the association and the company.

[64] Certain operators producing from the so-called "outside" leases are numbered among the most progressive in California, and the fact that they were unable to develop and produce the leases in accordance with the principles of good business and along accepted engineering lines was due to refusal of their lessors to allow them to cooperate with the participating companies.

[65] Patterson, R. C., Kettleman Hills' Tenth Anniversary: Petrol. World, February 1939, pp. 21–24.

the majority in order to develop oil pools in a manner known to produce greater profits and a greater percentage of the oil in the reservoir than can be acquired by operating in accordance with long-established interpretations of the "rule of capture"?

James A. Veasey, former general counsel, The Carter Oil Co., in the conclusion to a report[66] that he presented before the Section of Mineral Law of the American Bar Association and had for its purpose testing of the constitutionality of the principle of compulsory pooling of adjacent tracts into drilling units to conform to an established well-spacing plan, states:

"The wide spacing of oil wells through statutory enactment, and the corollary of pooling adjacent tracts to the end, which in turn will go far to prevent the drilling of unnecessary wells, has every justification. To begin with, the proposal clearly has constitutional support. In the next place, since the underlying purpose is to reduce the cost of production, the public interest will be promoted in the way of lower prices for oil products. The efforts of the industry for this reform have been frustrated by a very small minority of very selfish men. * * * Wider spacing and the prevention of the drilling of unnecessary wells is bound to come, because of the economic predicament of the petroleum industry. It is better that the reform should come through education, enlightened self-interest, and voluntary action on the part of the members of the industry. If what constitutes an overwhelming economic necessity cannot be met in the manner just indicated, then the industry must resort to the police power of the States to compel the proper spacing of wells and to pool adjacent tracts so that the underlying objectives fully may be attained."

Research in the laboratory and field combined with experience attained in forming unit agreements and developing and operating oil properties as units shows that, from both the technical and operating standpoints, unit operation presents no unsurmountable problems. Based upon engineering studies, reasonably accurate estimates can be made of oil and gas in pools and of the approximate quantity that for equitable distribution of the reservoir content should be allocated to the individual owners of the oil and gas rights. With the scientific instruments now available and the knowledge that has been gained in interpreting the results obtained through their use, engineers can determine with satisfactory precision all of the engineering factors that bear on the equitable distribution of the reservoir oil and gas, and the methods for bringing about such distribution with justice to all operators involved.

Legal considerations have been the real obstacle in the general utilization of oil pools, and so long as producing practices were based upon existing interpretations of the rule of capture and the reservoir oil and gas belonged to whoever reduced them to possession any plan for unitization of oil pools, naturally depended on voluntary and difficult-to-obtain agreements between the competing owners of the oil and gas rights in the common pool. In some States conservation legislation should be enacted or present laws interpreted more broadly in order that unitization of oil pools may be accomplished more easily. The Federal Government has taken a forward step by adopting the policy of requiring unitized operation of oil properties in areas where it holds prospective oil-bearing acreage.[67] California also, in approving the plan agreement for developing the deeper sands of the Buena Vista Hills, definitely has gone on record as favoring cooperative development of oil pools as a protection against waste of oil and gas.

The economic phase of unitization needs no elaboration other than to reemphasize that through unitization of common pools development and operating costs should be minimum and ultimate oil recovery from the pools maximum, and that equitable distribution of the reservoir content is attained because the respective landowners as tenants-in-common share in all oil and gas taken at any point from the pool in proportion as the recoverable content of each owner's land is to the recoverable content of the reservoir.

Thus, as ways have been found to overcome the engineering, legal, and economic problems, which in the past have tended to discourage a more general adoption of unit-operation plans, the main problem of unitization seems to hinge on the need for better understanding of the advantages of unitization by large and small operators, landowners, and all other interests in a common pool in order that the easily recognized theoretical benefits will become actual.

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[66] Veasey, James A., Compulsory Pooling: An address delivered before the Section of Mineral Law of the American Bar Association in Tulsa, Okla., July 25, 1938, p. 43. Printed in booklet form.

[67] On Aug. 21, 1935, Congress passed an act amending the Oil and Gas Leasing Act of Feb. 25, 1920, and providing for unitization of public lands.

## WASTE OF NATURAL GAS

One of the most important causes of waste of natural gas arises from the fact that approximately half of the natural gas produced in the United States is produced with oil. The production of gas with oil cannot be avoided, and the gas cannot be shut in entirely without shutting in the oil as well. Of course, where wells produce gas alone, withdrawals can be controlled, and wastage of gas results only when gas deliberately is blown to the air or an accident to the well or wellhead fittings causes gas to escape from the well. The volume of gas dissolved in and otherwise associated with oil in reservoirs varies; in some areas 200 or less cubic feet of gas is associated with each barrel of oil, whereas in others the proportion may be 5,000 or more to 1. On the average, perhaps, for the United States as a whole, the volume of gas produced with a barrel of oil is 2,000 to 2,500 cubic feet per barrel. Table 18 gives the average gas-oil ratios of 18 fields of which each produced 5,000,000 or more barrels of oil in 1938. These fields in that year produced 436,950,000,000 cubic feet of gas and 213,868,362 barrels of oil, or 2,043 cubic feet of gas per barrel of oil.

TABLE 18.—*Average gas-oil ratios of some oil fields (producing 5,000,000 or more barrels of oil in 1938) of the United States in 1938* [1]

| Field | Gas-oil ratio, cubic feet of gas per barrel of oil | Field | Gas-oil ratio, cubic feet of gas per barrel of oil |
|---|---|---|---|
| Dominguez, Calif | 1,968 | Rodessa, La | 4,481 |
| Huntington Beach, Calif | 1,230 | Eunice, N. Mex | 5,040 |
| Inglewood, Calif | 627 | Hobbs, N. Mex | 2,283 |
| Long Beach, Calif | 1,074 | Monument, N. Mex | 3,048 |
| Santa Fe Springs, Calif | 787 | Rodessa, Tex | 3,127 |
| Seal Beach, Calif | 703 | Conroe, Tex | [2] 250 |
| Wilmington, Calif | 423 | Hastings, Tex | [2] 400 |
| Ventura Avenue, Calif | 2,863 | Goldsmith, Tex | 1,864 |
| Kettleman Hills, Calif | 4,480 | Yates, Tex | 217 |

[1] Table compiled from data taken from Trans. Am. Inst. Min. and Met. Eng., Petroleum Development and Technology, 1939, vol. 132, New York.
[2] Estimated.

When a reservoir is tapped by the drill, oil is produced from the well because of expansion of the gas associated with the oil in the reservoir sands resulting from the difference in pressure between the sand face in the well and elsewhere in the reservoir. During the flush-production life of most wells the gas associated with the oil is the major source of energy driving the oil through the pore spaces in the reservoir rock to the wells. Its conservation, therefore, is of paramount importance in oil-recovery operations.

Conservation of gas may be defined as avoidance of waste in its use in propelling oil through the sands to wells and in utilizing the gas with maximum effectiveness after it has reached the surface of the ground. Gas under pressure with oil in reservoir sands is not wasted in the sense that it is lost to further use when oil-recovery operations are inefficiently performed unless, because of faulty well completion, the gas escapes through the well into overlying "thief" sands from which it cannot be recovered in the future. Only the energy of the gas can be dissipated wastefully in reservoir sands, but this section of the report deals only with volumetric waste, as energy relations in natural reservoirs have been discussed in earlier sections.

It has been estimated [68] that some 8 trillion cubic feet of gas have been wasted into the air from the start of the oil industry to 1935. Although the greater percentage of this waste occurred before 1934, when less effective methods of control were practiced and the markets for natural gas were more limited than they have been since that time, nevertheless, excessively large volumes still are being blown to the air in some oil-producing districts. In 1938 the waste of natural gas in Texas totaled 137.2 billion cubic feet,[69] approximately 12.5 percent

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[68] Garfias, Valentin R., Proven Reserves of Mineral Fuels in the United States: Trans. Am. Inst. Min. and Met. Eng., Petroleum Development and Technology, 1935, vol. 114, p. 243.

[65] Langford, C. M., Jr., Gas Statistical Report of the Railroad Commission of Texas: 1936–1937–1938, p. 4.

of the total gas produced. In the Panhandle field of Texas, however, where in 1934 the daily waste of gas into the air amounted to over 1 billion cubic feet, concerted efforts of operators and the Railroad Commission of Texas, backed by legislative measures to reduce wastage of gas, resulted in reducing wastage so that in 1938 only 13.6 billion cubic feet, or 2.2 percent of the total gas produced in that area, was blown to the air. In California gas blown into the air at the wells totaled 38.2 billion cubic feet in 1938, or 10.2 percent of all gas produced. Statistics on gas wasted in 1938 in other oil-producing States are not available, and the only recent estimate of the total volume of gas blown into the air in the United States is one made by Garfias,[70] who estimated that in 1934, 500 billion cubic feet of natural gas was blown into the air and wasted. In terms of heat units this enormous quantity of gas is approximately the equivalent of 87,500,000 barrels of crude oil of average gravity, or 650,000 carloads (50 tons to the car) of coal. That number of cars of coal would form a train (averaging 40 feet to the car) 4,925 miles long—a distance approximately equal to that from Houston, Tex., to New York and west to San Francisco, Calif.

Better methods of control and more rigid enforcement of legislation enacted in most of the oil- and gas-producing States probably are tending to reduce the wastage of natural gas in the United States gradually; nevertheless, it is believed that waste of gas continues to exceed consumption.

## PROGRESS IN CURTAILING WASTE OF GAS AND OIL IN THE TEXAS PANHANDLE FIELD

During midsummer of 1934, when an average of 1,000,000,000 cubic feet of natural gas per day was being blown into the air and wasted in the Texas Panhandle field, a committee composed of representatives of interested companies gave studied thought to the physical and economic waste of oil and gas occurring in the Panhandle field. That committee, in a report [71] prepared by J. G. Dickinson, superintendent of production, Texoma Natural Gas Co., Amarillo, Tex., concluded that "at the rate of 1,000,000,000 cubic feet (of gas) blown into the air the field will be exhausted in approximately 5 years." The gravity of that statement may better be appreciated when consideration is given to the fact that competent engineers estimated the original reserves in the Panhandle field as aproximately 16,100,000,000,000 [72] cubic feet of recoverable gas and 600,000,000 to 1,000,000,000 barrels of oil, depending on the allowance made for development of new areas in the field.

Most of the early waste of gas in the Panhandle field was "legalized" by the so-called "sour-gas law," which was an amendment to article 6008 of the act of 1931. The amendment as introduced in the legislature originally applied only to sour gas; [73] but as the law was passed it applied to "sweet" as well as sour gas. The amendment, in substance, limited the requirements that gas be confined until it can be utilized for light or fuel by providing that in all common reservoirs or pools consisting of more than 300,000 acres, where gas is found for which there is no reasonable market for light or fuel available to the owner, the gas may be utilized for other purposes, including the manufacture of natural gasoline, to the extent of 25 percent of the open flow of the well producing such gas, and under these circumstances utilization for purposes other than light and fuel shall not constitute waste.

The passage of the stripping law in 1933 caused an alarming waste of natural gas, which increased rapidly. At the same time there was very little increase in the consumption of residue gas for the manufacture of carbon black, with the result that the volume of gas blown to the air from gasoline plants increased from 205,685,000 cubic feet per day in February 1933 to 859,935,000 cubic feet per day in June 1934. There also was an additional volume of approximately 100,000,000 cubic feet of gas per day blown to the air from oil wells without being processed

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[70] Garfias, Valentin R., Work cited in footnote 68, p. 244.

[71] Pertinent parts of the report are given in the section "Waste of Gas and Oil in the Texas Panhandle" in Report on Petroleum Development and Production, by H. C. Miller and Ben. E. Lindsly, Petroleum Investigations (U. S. Congress, House of Representatives, Hearings on H. Res. 441, 73d Cong. Recess 1934), pt. II, pp. 1233–1240.

[72] Cotner, Victor, Bull. Am. Assoc. Petrol. Geol., vol. 17, No. 8, August 1933.

[73] "Sour" gas is natural gas containing hydrogen sulfide in such quantities as to make the gas unmerchantable for light and fuel purposes except at prohibitive expense for purification. Sour gas in the Panhandle field contains a small quantity of natural gasoline (about ⅓ gallon per thousand cubic feet), and when the gasoline was "stripped" from the gas the residue gas was blown to the air, except a small part used in the manufacture of carbon black.

through gasoline plants, making the total actual volume of gas blown to the air daily in the Panhandle field in June 1934 approximately 1,000,000,000 cubic feet.

Deplorable as it may have been, the monetary loss from wasting a billion cubic feet of gas a day was only part of the waste incident to the passage of the stripping law. The original formation pressure in the Panhandle field averaged only about 430 pounds per square inch, and the rapid withdrawal of gas, much of which was taken from wells producing only a trace of oil or none at all, caused the pressure to decline to 380, and in some areas where gas withdrawals were at an especially rapid rate, to 200 pounds per square inch. Natural gas is the principal expulsion agent driving oil to wells in the Panhandle field, and in testifying before the Railroad Commission of Texas competent engineers stated that wasting gas at the rate of a billion cubic feet of gas a day in the Panhandle field will result in the loss of 400,000,000 to 500,000,000 barrels of oil that would be recovered if reservoir pressures were maintained at approximately their original force by less rapid and more uniform withdrawal of the gas from the reservoir.

In May 1935 Texas House bill 266 became law. One of the purposes of the law was to stop continued wastage of gas; it provided that sweet gas can be used for light and fuel only; still permitted the use of sour gas for carbon-black manufacture; and definitely prohibited waste of either sour or sweet gas by blowing it into the air after the gas had been stripped of its gasoline. House bill 266 also contained a provision empowering the Railroad Commission to zone a field or reservoir into separate proration units.

Following passage of House bill 266, the Commission zoned the Panhandle area into two fields "for the reason that in the eastern part of the field, the leasehold and fee ownerships are divided into small tracts while, in the western portion of the field, the leasehold and fee ownerships are generally much larger in size. Also, the pipe-line markets for the east and west ends of the field are different. The west field is served by six major pipe lines and several local companies, with none of the lines extending into the eastern section of the field. The three major pipe lines and several local companies which operate in the East field all lead to Oklahoma or southern markets, with the result that under the present pattern there is no communication between lines serving the East field and those operating in the West field." [74]

The following facts and figures are taken from the Railroad Commission's annual report on the Texas Panhandle field. The report is dated August 1937 and covers operations in the field following passage of House bill 266.

A formation-pressure survey conducted during June and July 1935 showed that the weighted average pressure in the East field was 313.12 pounds per square inch. The field at that time had 393 wells with a daily potential of 6,802,370,000 cubic feet of gas. A similar survey, made in July 1937, showed that the average reservoir pressure had declined to 283.84 pounds per square inch or 29.28 pounds below that determined in June 1935. Total dry-gas production during the interval between pressure surveys was 3 552,395,000 cubic feet. During the same period, casing-head-gas production for the area average more than 140,000.000 cubic feet a day, of which 100,000,000 cubic feet came from the granite wash in the Kellerville area which carries only dry gas higher on the structure.

In July 1937 formation pressures had almost reached the critical pressure from the pipe-line standpoint, and booster stations soon would be needed to raise the pressure to that required to transport it from the field if the demand for gas was maintained at the July 1937 rate.

Cessation of stripping increased the formation pressures in the Le Fors area from an average of 140 pounds per square inch in June 1935 to an average of 154 pounds per square inch in July 1936.

The number of wells in the West field increased from 537 with a potential of 8,804,095,000 cubic feet of gas in June 1935 to 624 with a potential of 10,153.657,000 cubic feet of gas in July 1937. During that period the withdrawal of 14,924,069,000 cubic feet of gas (not including casing-head gas) caused a drop of only 8.92 pounds per square inch in the formation pressure—from 378.82 pounds per square inch in June 1935 to 369.90 in July 1937.

The sour-gas area in the northern part of the West field was developed by 224 wells in June 1935; in July 1937 there were 357 wells, and an intensive drilling

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[74] Railroad Commission of Texas, Annual Report on the Panhandle Oil and Gas Field: Austin, Tex., August 1937, p. 3.

campaign was underway to provide more wells to furnish the ever-increasing demand for gas for the manufacture of carbon black. The potential of the area increased from 2,651,465,000 cubic feet of gas in 1935 to 6,918,229,000 in July 1937. The weighted average formation pressure was 359.72 pounds per square inch in June 1935 and 345.28 pounds per square inch in July 1937. During the 2-year period 331,268,077,000 cubic feet of sour gas were withdrawn from the area.

Table 19 shows the volumes of natural gas produced in the different areas of the Panhandle field, the volumes of gas utilized, the volumes wasted, and their percentage of the total gas produced.

TABLE 19.—*Sweet, sour, casinghead, and total natural-gas production, utilization, and wastage in the Texas Panhandle oil and gas field*

| Year | Natural-gas production, 1,000 cubic feet | | | | | |
|---|---|---|---|---|---|---|
| | Sweet | | | Sour | Casinghead | Total |
| | East field | West field | Total | | | |
| 1935 (last half)[1] | 43, 701, 290 | 103, 125, 555 | 146, 826, 845 | 63, 070, 053 | 68, 465, 650 | 278, 362, 548 |
| 1936 [1] | 43, 383, 450 | 231, 044, 684 | 274, 428, 134 | 170, 649, 091 | 152, 352, 702 | 597, 429, 927 |
| 1937 [2] | 41, 272, 571 | 236, 725, 209 | 277, 997, 780 | 222, 638, 166 | 135, 865, 107 | 636, 501, 053 |
| 1938 [2] | 40, 214, 563 | 230, 292, 936 | 270, 507, 499 | 221, 979, 183 | 114, 434, 288 | 606, 920, 970 |

| Year | Utilization, 1,000 cubic feet | | | | Wastage | |
|---|---|---|---|---|---|---|
| | Extraction loss | Plant lease and other use | Manufacture of carbon black | Delivered to pipe lines | 1,000 cubic feet | Percentage of gas produced |
| 1935 (last half)[1] | 12, 193, 982 | 35, 723, 662 | 81, 785, 734 | 63, 057, 516 | 85, 601, 654 | 30. 8 |
| 1936 [1] | 23, 021, 964 | 83, 905, 538 | 223, 432, 855 | 202, 291, 255 | 64, 778, 315 | 10. 8 |
| 1937 [2] | 24, 256, 526 | 72, 252, 871 | 288, 409, 978 | 234, 736, 498 | 16, 853, 550 | 2. 6 |
| 1938 [2] | 22, 269, 391 | 66, 227, 873 | 268, 479, 209 | 235, 040, 862 | 13, 636, 010 | 2. 2 |

[1] Compiled from data given in oil and gas division, Railroad Commission of Texas, Annual Report on the Texas Panhandle oil and gas field, Austin, Tex., August 1937.

[2] Data furnished by the Railroad Commission of Texas.

Stripping was still the common practice in 1935 and continued during the first 2 months of 1936. Subsequently, gas production was held to demand levels, with the casinghead production varying only several million feet a day, the sweet gas keeping pace with the seasonal demand and the sour-gas production increasing from 383,695,000 cubic feet a day in April 1936 to 588,277,000 cubic feet a day in June 1937. During the same period, wastage of natural gas decreased from 30.8 percent (average for the last 6 months of 1935) to an average of 3.7 percent for the first 6 months of 1937.

Efforts of the Railroad Commission of Texas to secure "uniform, proportionate, and ratable" withdrawals of gas in the Panhandle field continued throughout 1937 and 1938. In May 1937 Senate bill 407, providing that production of wells may be prorated to prevent noticeable and preventable drainage of gas across property lines, became a law. This act applies only to the Panhandle gas field because it is the only gas field in Texas producing both sweet and sour gas. On May 1, 1938, the commission issued order 10–316, based on authority invested in it by passage of Senate bill 407, to establish daily allowables and allocation between wells in the sour-gas part of the west area of the Panhandle field. After determining monthly nominations for sour-gas demand to pipe lines, gasoline and carbon-black plants, the order allocates allowable withdrawals to individual wells on the basis of one-third to well potential and two-thirds to the product obtained by multiplying the acreage containing the well by the observed formation pressure at the well. This method of allocation was adopted after a considerable amount of study by the

Commission's engineers. It was thought to be more equitable to all concerned and to approach more closely withdrawals with respect to gas in place than by placing the allocation of the field's allowable to individual wells on a 50-percent potential and 50-percent acreage basis, arbitrarily assigning each unit 640 acres as provided in previous orders issued by the Commission and invalidated by the courts.

Reporting on the results of studies of the sour-gas-field situation by the commission engineers, the new order states in part: [75]

"The commission finds that the withdrawal of dry natural gas from the sour gas area of the West Panhandle field have been throughout the history of the field, nonuniform, disproportionate, and unratable.

"The commission finds that there is now, and there has been for some time past, undue, preventable, and cognizable drainage of gas between tracts of land in the West Panhandle gas field, and that this undue drainage between tracts has been brought about by disproportionate, nonuniform, and unratable withdrawals of gas between properties and wells, as has been illustrated by testimony.

"The commission finds that unless there be a restriction in the amount of production of sour natural gas as provided by statute, and a distribution of such production by a formula which operates to prevent said undue drainage between properties, the present system of nonuniform, disproportionate, and unratable withdrawals will continue and differentials in pressure will be accentuated, with resultant undue drainage between tracts of land.

"In order to approach uniform withdrawals from the sour gas area of the West Panhandle field, the gas must be taken ratably with respect to the reasonable production requirement. In establishing ratable production, it is necessary for the commission, first, to determine an efficient drainage area, and second, to devise a fair and uniform system of proration to be applied to the field."

The act and order were attacked by the Henderson Co., but in a hearing before a three-judge court their validity was sustained.[76]

According to Hardwicke: [77]

"A decision in the case brought by Consolidated Gas Utilities Corporation, now pending, should determine finally whether it is possible in a field where problems are as complicated and complex as in the Panhandle Field for an order ever to be written and sustained which undertakes to restrict the production from sweet gas wells so as to prevent drainage across property lines. So far the Commission has not been able to write such an order, although it has finally, after years of litigation, succeeded in establishing the existence of the power, and has successfully applied the power as to an operator in the sour gas area who was shown to be draining his neighbors. The factual situation in the Panhandle Field, is, however, so complex, and the fact findings of previous decisions so unfavorable, that it may be that the Commission in some respects has won an empty victory in having finally secured a judicial recognition of the principle it has asserted throughout the years, being the right of the State to provide for the regulation and proration of oil and gas production in the protection and adjustment of the correlative rights of the owners of a common oil and gas pool, and in the prevention of undue and disproportionate takings. Whether the over-all production history, pressure gradients and drainage tendencies are such as to prevent the successful application of the principle to sweet gas wells in the Panhandle remains to be seen. Certainly, the power can be exercised in new fields where past practices have not presented equities and other complications similar to those found in the Panhandle Field."

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[75] Railroad Commission of Texas, Oil and Gas Division, Order No. 10–316, May 1, 1938; see also Tucker, Michell, Proration is Invoked again in Panhandle Sour Gas area: Oil and Gas Jour., June 9, 1938, p. 31.

[76] See Henderson vs. Terrell, 24 F. Supp. 147 (W. D. Tex., July 23, 1938) where the court followed the Supreme Court's ruling in the Consolidated Case (*Thompson* vs. *Consolidated Gas Utilities Corporation*, 300 U. S. 55 S. Ct. 364, 81 L. Ed. 510), by holding that the police power of the State extends to preventing drainage of oil or gas from under the land of another.

[77] Hardwicke, Robert E., Legal History of Conservation of Oil in Texas: Chapter in a symposium, entitled "Legal History of Conservation of Oil and Gas," published by the section of mineral law of the American Bar Association, December 1938, p. 286.

As shown by the figures in table 19 for percentage of gas wasted in the Panhandle Field—2.6 percent in 1937 and 2.2 percent in 1938—wastage of gas has been reduced almost to a practical minimum, considering that the gas is produced from over 4,000 oil and gas wells and from 1,500 wells producing gas only. According to C. C. Anderson, petroleum engineer, Bureau of Mines, Amarillo, Tex., in a letter to the writers:

"A considerable amount of the present waste is due to the inability of the production departments, gasoline plants, pipe-line companies marketing fuel gas, and carbon-black plants to keep their various operations in step. For instance, if something happens at the carbon-black plants to cause a partial shut-down, or fuel demands drop off before the production departments have made their daily oil allowables, there is little that the gasoline plants can do except 'pop' the residue casing-head gas to the air following the extraction of gasoline."

Judging from the progress that has been made in reducing the volume of gas blown to the air in the Texas Panhandle field—from 1 billion cubic feet per day in 1934 to approximately 37 million cubic feet per day in 1938—admirable progress has been made in regulating production, preventing waste, and recognizing the equities of the small units of the industry that cannot find markets for their gas without laying long pipe-line systems that are beyond their ability to finance. However, the task has not been completed, as much remains to be done in settling the difficulties. All operators abhor waste of gas, but the companies with pipe lines and marketing facilities desire to supply their markets from their own properties, whereas operators without such facilities want the pipe-line companies to take a pro rata share of the production from their properties. A pro rata share may not necessarily be an equitable share, and the question of who is to install gathering lines and other details complicates the situation materially.

Conflict between such points of view has led to waste of gas, and adjudication of differences remains the "order of the day" in the portfolio of the Texas Railroad Commission. Last winter a bill to prorate the sweet-gas part of the field, similar to the sour-gas law that went into effect in 1938 and has been upheld by the courts, was considered by the Texas Legislature but did not pass.

## WASTE OF NATURAL GAS IN CALIFORNIA

During the 5-year period 1934–38, with the possible exception of 1938, when approximately 10 percent of the gas produced in California was wasted, the volume of gas blown to the air has been close to an irreducible minimum. Only a few fields in California produce gas alone; 95 percent, approximately, of the natural gas is produced in conjunction with oil-producing operations. The volume of gas produced and wasted in California depends, therefore, mainly upon the quantity of oil produced.

The discovery and rapid development of a number of new oil fields in California in which large volumes of gas were associated with the oil in the reservoir sands resulted in a slight increase in the volume of gas wasted during 1938. For several years the wastage of gas had declined steadily, and in 1937 only 5.3 percent of the gas produced in California was blown to the air. In 1938, however, the volume of gas wasted was 10.2 percent of the total produced.

Table 20 summarizes conditions in California from 1934 to 1938, inclusive, as they pertain to oil production and to gas production, utilization, and wastage. The segregation of casinghead and dry-gas production (gas produced from wells producing gas only) shows the predominance of gas produced in conjunction with oil production. The table shows that gas wastage reached a minimum in 1937, when 5.3 percent of the gas produced was wasted—only 80 cubic feet for every barrel of oil produced. During 1938, however, mainly because of wastage of gas in the Wilmington field, 10.2 percent of the total gas produced was blown to the air—153 cubic feet for every barrel of oil produced.

Of the total quantity of gas wasted in California in 1938, oil-producing operations in the Wilmington oil field were responsible for wasting 25 percent. During that year, 34,190,382 barrels of oil was produced with 19,372,740,000 cubic feet of gas, of which 9,611,835,000 cubic feet (49.6 percent) was blown to the air—281 cubic feet for every barrel of oil produced.

TABLE 20.—*Oil production and natural-gas production, utilization, and wastage in California, 1934–38, inclusive*

| Year | Oil production, barrels [1] | Natural gas [2] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Casinghead, M cubic feet | Dry, M cubic feet | Total, M cubic feet | Utilization, M cubic feet | Wastage | |
| | | | | | | M cubic feet | Percentage of gas produced |
| 1934 | 175, 508. 566 | 283, 142, 012 | 4, 957, 292 | 288, 099, 304 | 269, 524, 394 | 18, 574, 910 | 6. 5 |
| 1935 | 207, 832, 131 | 307, 313, 874 | 11, 801, 258 | 319, 115, 132 | 296, 045, 463 | 23, 069, 699 | 7. 2 |
| 1936 | 214, 733, 315 | 338, 079, 684 | 5, 784, 611 | 343, 864, 295 | 319, 403, 271 | 24, 461, 024 | 7. 1 |
| 1937 | 238, 520, 383 | 343, 142, 734 | 11, 621, 318 | 354, 764, 052 | 335, 800, 628 | 18, 963, 424 | 5. 3 |
| 1938 | 249, 749, 246 | 362, 054, 223 | 13, 781, 266 | 375, 835, 489 | 337, 601, 673 | 38, 233, 816 | 10. 2 |

[1] Figures compiled by G. R. Hopkins, Bureau of Mines.

[2] Figures compiled from data furnished by State of California, Department of Natural Resources, division of oil and gas.

During 1938, 6,459,544,000 cubic feet of gas—253 cubic feet for every barrel of oil produced—was blown to the air in the Kettleman Hills oil field, 16.9 percent of the total volume of gas wasted in California during that year. During 1937, however, gas wastage in the Kettleman Hills field totaled 13,003,660,000 cubic feet, 447 cubic feet for every barrel of oil produced. This waste of 13 billion cubic feet of gas represented 68.6 percent of the total unconserved gas in California in 1937.

Rapid development, initiated late in 1938, of deep zones in the West Montebello oil field in southern California resulted in the waste of excessive volumes of gas that continued until June 1939, when the Department of Natural Resources, Division of Oil and Gas, of the State of California obtained orders from the court under previously enacted laws governing gas wastage[78] designating 250 barrels of oil as the maximum a well legally could produce per day from the deep zone (7th zone) in the West Montebello field. Gas-oil ratios of wells completed in this zone range up to 6,000 and average 3,000 cubic feet of gas per barrel of oil, and the orders were issued on the ground that curtailing oil production was the only practical way to conserve the large quantity of gas which was being blown to the air.

The State is making every effort to reduce the waste of gas to an irreducible minimum. Unfortunately the gas-conservation act has not proved to be an altogether effective measure to bring the unwilling-to-cooperate producer in line, mainly because of different interpretations of what constitutes "unreasonable" waste; but fortunately, most operators in California appreciate the value of producing oil with low gas-oil ratios and are willing to prorate and curtail output of oil to reduce the waste of gas and to store surplus gas, when its production cannot be avoided, in commercially depleted oil sands.

## SUMMARY STATEMENT

A review of developments and achievements in methods and processes constituting phases of technology in the petroleum industry during the past 5 years brings out the significant conclusion that the overwhelming trend in the industry is toward application of science and engineering in exploration, drilling, and producing operations.

The finding of new accumulations of petroleum has become a highly specialized and scientific art, and the fact that subsurface structures thousands of feet lower than the present deepest producing reservoirs can be mapped by geophysical methods indicates widespread possibilities of the maintenance of the Nation's petroleum reserves for some time to come. That development technique and methods have paced advancements in finding deep-seated structures favorable for the accumulation of oil and gas is attested by the increasingly greater number of boreholes drilled to depths exceeding 10,000

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[78] Sec. 8B, act of June 10, 1915, prohibiting unreasonable waste of natural gas has been upheld as constitutional and, therefore, cannot be rendered inoperative by injunctions although operators have a right to challenge in court the method and amount of restriction requested by the State.

feet and the success attained in California in penetrating the surface of the earth to a depth of 15,004 feet.

The producing branch of the petroleum industry confidently expects to be able, and based on past progress in producing methods and technique will not fail, to produce oil from any depth attained by the drill and to recover an increasingly higher percentage of the recoverable oil from reservoirs by more efficient utilization of the inherent energy resources at rates equal to or even greater than present withdrawals. Engineering methods resulting from research and already applied have pointed out the possibility of utilizing the high-head water in the extraneous parts of many oil-bearing reservoirs to maintain flow from wells throughout their producing life. However, when, for one reason or another, because of the absence of high pressures in the reservoirs or the lack of coordination of production practices, oil eventually must be pumped from deep-seated reservoirs, engineers, oil producers, and manufacturers of pumping equipment will find ways to bring the oil to the surface of the ground.

It is becoming more generally recognized that the best achievable engineering practices and soundest economic principles cannot be handled separately, and to a growing extent the industry is giving greater thought to the physical and economic evils of too-close spacing of wells and the fallacy of drilling more wells in a pool than is necessary for economic recovery of oil therefrom. Pool development and exploitation in accordance with the "rule of capture"—the antithesis of efficient oil recovery—are being superseded rapidly by methods and technique developed as means for more easily circumscribing the rule rather than attempting to "repeal" it by legal methods.

Through voluntary action by lessees and fee owners in a common pool, with legal sanction in many States and the support of the National Government where Federal lands are involved, unit operation of pools under diversified ownership is increasing, to take advantage of the benefits to be derived from such practices in greater ultimate oil recovery and lower development and operating costs. However, the difficulties incident to the inability of all producers in many common pools to "get together" and unitize their holdings and many other reasons why such optimum operation of pools has not been adopted more widely have caused the oil industry, because of its ability to produce more oil than is needed immediately, to depend on proration as the next best method for conducting its operations efficiently.

Proration, as generally practiced in many fields, however, fails to affect equitable withdrawal of oil from a common pool because the well rather than the recoverable oil reserve in the pool usually is considered the ultimate unit for allocation, and no consideration is given to the percentage of the total reserve owned by the individual operators. In other words, unless proration formulas give liberal allowance to acreage so as to permit consideration of the quantity of oil underlying the respective tracts in a pool, equity in the distribution of the oil in a pool is not attained. Without consideration of acreage, proration policies create incentives for operators to drill more wells than necessary to drain the oil from the pool, as well as to produce the oil at rates in excess of market requirements. Obviously, without seriously affecting its economic status, the industry cannot continue to increase its numbers of producing wells while wells already operating can produce efficiently more oil than markets can absorb.

Attainment of the maximum ultimate economic recovery of the oil from pools, equitably apportioned among the various surface owners, depends, therefore, on unitization of oil pools or systematized proration so administered that the maximum effective use can be made of the gas, water, and reservoir energy in the production of the oil.

Mr. Cole. We will adjourn at this point until 10:30 tomorrow morning.

(Thereupon, at 4:05 p. m., an adjournment was taken until 10:30 a. m. of the following day, Wednesday, November 8, 1939.)

# PETROLEUM INVESTIGATION

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WEDNESDAY, NOVEMBER 8, 1939

House of Representatives,
Subcommittee of the Committee on
Interstate and Foreign Commerce,
*Washington, D. C.*

The subcommittee met, pursuant to adjournment, at 10:30 a. m. in the committee room, New House Office Building, Hon. William P. Cole, Jr., presiding.

Mr. Cole. The committee will please come to order.

## STATEMENT OF HON. HARRY R. SHEPPARD, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Mr. Cole. Mr. Sheppard, of California, is in the room. Mr. Sheppard, if you desire to make any statement, the committee will be glad to hear you.

Mr. Sheppard. Pardon me, Mr. Cole.

Mr. Cole. I just noted in the record that you were here and asked you if you wanted to make any statement.

Mr. Sheppard. No; merely as a very interested spectator.

## STATEMENT OF HALE B. SOYSTER, CHIEF, OIL AND GAS LEASING DIVISION, DEPARTMENT OF THE INTERIOR

Mr. Cole. Mr. Soyster, we will be glad to hear you. We know who you are. You have been before us before, but for the purpose of this record will you give your full name and present position?

Mr. Soyster. My name is Hale B. Soyster, Chief of the Oil and Gas Leasing Division of the Geological Survey.

I graduated from the University of California in 1922 in economic geology and petroleum engineering.

Before graduation, I spent considerable time working in the oil fields in California at all sorts of jobs from hoeing weeds up. Upon graduation I was employed by the Superior Oil Co., of California, where I stayed for some time until I resigned and entered the consulting-engineering business in Los Angeles.

In 1924 I went to work for the United States Bureau of Mines at Bartlesville, Okla., as associate petroleum technologist. Subsequently I was moved from place to place in Oklahoma; my duties at that time were related to the supervision of oil and gas operations, primarily on restricted Indian lands.

In 1925 the Bureau of the Mines was transferred to the Department of Commerce by Presidential order and the oil and gas leasing and regulatory work was transferred to the Conservation Branch of the Geological Survey, where it has since remained.

In 1928 I was appointed oil and gas supervisor of the midcontinent district of the Geological Survey, having jurisdiction over all of the midcontinent States in which there were either Indian or public lands. In addition to that, it included the State of Michigan. In 1928 I was loaned to the State of Michigan for a brief period of time to aid that State or the officials of that State, in drafting regulatory measures with reference primarily to the Muskeegan field in Michigan.

In 1930 I was transferred to Casper, Wyo., as supervisor of the Rocky Mountain district, which included all of the Rocky Mountain States, and in 1932 was transferred to Washington as Chief of the Oil and Gas Leasing Division, which position I have held since that time.

I also participated in the preparation of the material that was prepared by the Geological Survey for your committee during the investigation which was made in 1934.

Mr. COLE. At this point your work is bringing up to date part II, referring to public petroleum lands of the hearings of 1934?

Mr. SOYSTER. That is correct.

Mr. COLE. Who assisted you with this work?

Mr. SOYSTER. I have that covered in this statement.

Mr. COLE. Very well.

Mr. SOYSTER. The Oil and Gas Leasing Division of the Conservation Branch of the Geological Survey has supervisory and regulatory authority over all operations for oil and gas on lands of the public domain, restricted, allotted, and tribal Indian lands, except the Osage Indian Reservation in Oklahoma and through a cooperative agreement with the Navy Department, performs similar functions with reference to the naval petroleum reserves.

This division of the Geological Survey is also responsible for all royalty accounting—that is, the computation of royalties accruing to the United States and to the Indians from operations upon public lands, naval petroleum reserves, and Indian lands. There are some few exceptions with reference to Indian lands. For instance, in the State of New York there is a small amount of production from Indian lands; also in Michigan, where we do not do any royalty accounting; no accounting work is performed for the Osage Indian Reservation in Oklahoma.

The Oil and Gas Leasing Division has four supervisory districts: One headquartered in Casper, Wyo.; one in Roswell, N. Mex.; one in Tulsa, Okla.; and one in Los Angeles, Calif.

Under these supervisory offices we have approximately 18 subfield offices in charge of a district engineer. The personnel of the division has approximately 100 employees.

The material prepared in the Conservation Branch of the Geological Survey supplements the report of your committee in 1934 and an endeavor has been made to review the developments since that time.

The section entitled "Oil and gas leases on the public domain" was prepared by Mr. Max Barash, of the General Land Office, and Mr. Paul H. Salomon, of the Geological Survey. The sections entitled "Petroleum leases on Indian lands" and "Prevention of avoidable waste at the Osage Reservation, Okla." were prepared by Mr. Floyd L. France, of the Office of Indian Affairs; and the section entitled "Prevention of avoidable waste on public and Indian lands (except Osage Reservation) and the extent to which results are affected by private operations on contiguous non-Federal leases" was prepared by Mr. Paul H. Salomon, of the Geological Survey, with the advice and assistance of petroleum engineers in the Geological Survey. The section entitled "Progress of unit operation of oil and gas fields involving Federal lands" was prepared by Mr. John F. Deeds, of the Conservation Branch, with the advice and assistance of petroleum engineers of the Geological Survey.

Mr. COLE. Are any of the gentlemen who assisted you in the work present?

Mr. SOYSTER. Yes, sir; one, Mr. Salomon.

Mr. SALOMON. My name is Paul H. Salomon, Mr. Chairman.

Mr. COLE. On behalf of the committee, Mr. Soyster, I want to thank you, your staff, and others who have testified in the past few days on the technical part of this work for the splendid assistance you have given the committee. It is another illustration of what can be done with a department of the Government cooperating with the committees of Congress in investigations such as we are asked to conduct with limited funds.

Mr. SOYSTER. Thank you, Mr. Cole.

Mr. COLE. All without bias; without expression of opinions other than those that are asked for, and from the technical standpoint I am sure they are going to be received with the same favor from the industry and those interested throughout the country as the work was in 1934.

Mr. SOYSTER. Since the committee's report in 1934 the Congress has enacted legislation amending the basic Oil and Gas Leasing Act of February 25, 1920 (41 Stat. 437), which is of paramount importance in the conservation of the Nation's oil and gas resources on the public domain. The legislation referred to is the act of August 21, 1935 (49 Stat. 674). This act makes certain fundamental changes in the method of disposing of oil and gas deposits on the public domain so as to provide for a more businesslike development of these important natural resources and a return to the United States of a royalty commensurate with the royalty schedule paid under oil and gas leases on State and privately owned land. The changes made are discussed in some detail in the material which has been prepared and submitted to your committee.

### LEGISLATIVE AUTHORITY FOR UNIT OF COOPERATIVE DEVELOPMENT

As a conservation measure the amendatory act referred to will undoubtedly have a far-reaching effect in conserving the irreplaceable oil and gas resources on the public domain. It vests in the Secretary of the Interior the power to require the development and production of oil and gas deposits under such unit or cooperative plans of development and operation as the Secretary may deem necessary in the public interest. In contrast with the acts of July 3, 1930, and March 4, 1931, which authorize the Secretary of the Interior, with the consent of the holders of the permits and leases involved, to approve unit or cooperative plans of development and operation for any single oil or gas pool or field, while the amendatory act of August 21, 1935, empowers the Secretary to require that all leases thereafter issued be conditioned upon an agreement by the lessee to operate under such reasonable cooperative or unit plan for the development and operation of the area, field, or pool as the Secretary may determine to be practicable and necessary or advisable.

In addition to the authority vested in the Secretary by the 1931 act to alter or modify from time to time in his discretion the quantity and rate of production under any unit or cooperative plan of development, the amendatory act of August 21, 1935, vests in the Secretary authority to alter or modify from time to time in his discretion the rate of prospecting and development and the quantity and rate of production under any such plan.

The original leasing act of February 25, 1920, established certain acreage limitations above which a lessee could not hold acreage. The limit was 7,680 acres in any one State and 2,560 acres on any one structure.

### ACREAGE LIMITATIONS

In order to encourage unit or cooperative operations and induce holders of leases to operate under such reasonable plans for the development and operation of an area, field, or pool, as the Secretary may determine to be practical and necessary or advisable, the amendatory act of August 21, 1935, provides that all leases operated under such a plan approved or prescribed by the Secretary shall not be subject to the acreage limitations prescribed by section 27 of the Leasing Act of February 25, 1920.

There are additional forms of inducement to enter into unit or cooperative plans and other acts which authorize relief from previous requirements or other requirements of the law.

The act of February 9, 1933, provided that any lessee who suspended operation for any reasonable period of time——

Mr. Cole. Will you suspend for just a moment, Mr. Soyster?

Mr. Soyster. Yes, sir.

Mr. Cole. You may proceed.

Mr. Soyster. I was speaking of measures of relief offered by the Federal Government and inducements to enter into plans of cooperative or unit development.

One of the acts which was passed in an endeavor to encourage conservation and recognized efforts in that direction was the act of February 9, 1933. That act provided in brief that any lessee of Government lands who suspended operations for a period of time could receive a suspension of rental for that period; that is, for the period of suspension of operations and production. And, in the case of 20-year leases, this act, of course, is particularly applicable, since leases were issued under the February 25, 1920 act, for a definite term. Such a suspension of operations and production and relief from the payment of rental, as well as the extension of the leases, have been assented to for the purpose of conservation; that is, to permit the suspension of operations during the period when the prices are so low that the national resources are being depleted at a figure below their real value; and also to permit the conservation of energy in areas where there is no present market for the gas as well as the oil.

Also in connection with this act, we do not authorize relief any time upon the application of any lessee who has a desire to suspend operations. In depends first of all upon whether there is an element of conservation involved; secondly, as to whether or not public lands or Indian lands involved in the application for a suspension are subject to drainage of oil or gas by lands that are adjacent or even those on the same structure which are not under governmental jurisdiction and whether granting such relief would adversely affect the leaseholds of the restricted Indians or the property of the United States. In such cases we have granted authority to suspend upon the agreement to pay compensatory royalty; that is, a royalty estimated to reimburse the United States or the restricted Indians, for the loss of royalty through drainage. An estimate is made as to the amount of drainage and each month the lessee obtaining that relief is billed for that amount in addition to any other amounts considered to be done under the provisions of the lease.

Indian lands, while leased under a variety of leasing regulations are, with the exception of the Osage Reservation, operated under one set of rules, the oil and gas operating regulations approved November 1, 1936, of the Interior Department. A standardized lease form has been adopted which is drafted with a view to the protection of public interest and the interest of restricted Indians. The standard lease form and the regulations provide for a special well-spacing and casing program subject to departmental approval. Drilling and producing restrictions may, under certain conditions, be imposed by the Secretary. Lessees agree to subscribe to and abide by agreements for the cooperative or unit development of the field or area affecting the leased Indian land.

### UNIT OPERATION OF PUBLIC LANDS

As previously stated, the present authority for the approval of unit or cooperative plans of development and operation is included in the amendatory act of August 21, 1935.

Unitization of Federal oil and gas deposits was first authorized by the temporary act of July 3, 1930 (46 Stat. 1007), amending sections 17 and 27 of the Mineral Leasing Act of February 25, 1920. This law terminated at midnight on January 31, 1931, but was reenacted as permanent legislation in substantially identical language in the act of March 4, 1931 (46 Stat. 1543). The act of August 21, 1935, further amended section 17 of the mineral leasing act of 1920, and added certain additional revision to the unitization clauses contained in the 1931 amendment.

### REGULATIONS

The General Land Office Circular No. 1252, approved June 4, 1931, contains the regulations under the act of March 4, 1931, which prescribe the procedure for the preparation and submission of unitization agreements. It is therein provided that any cooperative or unit plan of development and operation of a single pool or field after discovery of oil and gas must be by agreement of all Government lessees and permittees or their representatives and the owners or lessees of the lands not privately owned, or by such of these separate interests as will give effective control of development and operation of the area. The regulations specify the type of information which must be submitted to permit a determination by the Secretary of the

Interior that a unit or cooperative plan is necessary or advisable in the public interest.

These regulations further provide that the agreement must contain a provision giving authority, limited as agreed upon and therein fixed, under which the Secretary of the Interior may alter or modify the rate of prospecting and development and the quantity and rate of production under the plan.

That is a provision of the law and must be inserted in all unit agreements or cooperative agreements of whatever form. However, the extent to which control is extended to the Secretary is limited by the agreement of the parties involved in each particular plan that may be considered.

Under date of April 4, 1932, regulations were issued requiring that all oil and gas prospecting permits, or extensions of previously issued permits, contain a covenant for the submission of an acceptable plan for the prospecting and development as a unit of the pool, field, or area affecting the permit lands. General Land Office Circular 1386 approved May 7, 1936, contains the current regulations governing the issuance of oil and gas leases for Federal lands. Pursuant to these regulations, leases now being issued contain the following covenant [reading]:

> Within 30 days of demand, to subscribe to and operate under such reasonable cooperative or unit plan for the development and operation of the area, field, or pool embracing the land included herein, as the Secretary of the Interior may determine to be practicable and necessary or advisable, which plan shall adequately protect the rights of all parties in interest, including the United States.

On October 30, 1936, the Secretary of the Interior approved, effective November 1, 1936, uniform oil- and gas-operating regulations applicable to lands of the United States and to all restricted tribal and allotted Indian lands, except the Osage Indian Reservation. These regulations were made effective as to public lands in the naval petroleum reserves under jurisdiction of the Navy Department by approval thereof by the Secretary of the Navy on November 7, 1936. These regulations, which govern the development and production under Federal auspices of oil, gas, and casing-head or natural gasoline, including propane, butane, and other hydrocarbons, are made a part of all agreements for unit or cooperative development. They thus become binding on all parties to the agreements, irrespective of land ownership.

The procedure established under the foregoing regulations makes the General Land Office the office of record as to oil and gas rights involving Federal lands and vests in the Geological Survey jurisdiction of all operations for the discovery and production of oil and gas. Unitization is a functional activity involved in the latter category and the primary responsibility for the preparation, approval, and enforcement of unitized operations rests with the Geological Survey.

### OBJECTIVES OF UNITIZATION UNDER FEDERAL STATUTES

All cooperative or unit plans approved by the Secretary of the Interior must contemplate attainment of three fundamental objectives, (1) the natural resources of the unitized area must be conserved, (2) authority to control operations and production must be vested in the Secretary of the department having jurisdiction, and (3) the interests of all parties signatory to such an agreement must be protected.

Mr. Wolverton. Mr. Soyster, may I inquire whether this bill now before the committee increases the authority or jurisdiction of the Interior Department with reference to unitization?

Mr. Soyster. I will answer that the best I can, Mr. Wolverton. In my opinion it does not. That is my understanding of the bill. It makes likely unit and cooperative development and operation of some kind because basic fundamental principles of engineering are involved. and in order to apply those principles and accomplish conservation required by the bill cooperative action of some kind in the development and operation of an oil pool or field may be expected.

Mr. Wolverton. The basic principle of the bill, as I understand it, is to give greater jurisdiction to the Department of the Interior or the bureau to be created in the Department for conservation. I assume that this unitization which you now refer to has the purpose of and is to provide greater oil recovery, and thereby eliminate a wasteful feature.

Mr. Soyster. That is correct. As I said, one of the three fundamental reasons for unitization was the conservation of natural resources.

Mr. Wolverton. For that reason, I am inquiring whether the provisions of the bill would enlarge the jurisdiction of the Department with respect to it.

Mr. Soyster. In my opinion, the bill does not make mandatory unit or cooperative development; it simply requires practices which of necessity, in some cases, may result in unit or cooperative development and operation because those engineering factors or principles which the bill defines as the basis of ascertaining waste cannot be applied effectively if the pool or field is not developed and operated under a cooperative or unit plan. To my knowledge there is nothing in this bill that enforces or requires the holders of patented lands to join a unit or cooperative plan.

Mr. Wolverton. It probably does not make reference to it as directly as you have stated, but whether the authority which is sought to be created in the Department to make recommendations with respect to the elimination of wasteful methods, in effect constitutes or creates authority to act more definitely than by a mere recommendation and thereby could order the adoption of a unit system of operation.

Mr. Soyster. I do not quite understand the way in which you consider it has an effect, so that I am at a loss to answer your question.

Mr. Wolverton. You are of the opinion, evidently, that because there is not a direct reference in the bill to unitization that therefore it is not the intent of the bill to cover that.

Mr. Soyster. No, no; I would not say that. I would not say that it is not the intention of the bill to cover it. I would say that if the bill becomes law and was actually enforced, it certainly would be hoped that it would be possible under that law to take action which would at least encourage unit operations.

Mr. Wolverton. I understand the thought you have in mind, but is there any general language in the bill that might enable the Department to go beyond mere encouragement, to the point of direction?

There are provisions in the bill that make it possible for crimes to be committed by those who do not comply with the recommendations or findings of the Department, and I am wondering if this would be one of the features that might be utilized beyond encouragement, to the point of direction.

Mr. SOYSTER. I think that—this is my personal opinion. I am not speaking now for the Geological Survey or the Department either; I am just telling you what I think at this particular point, and that is that there is not any specific language in the bill under which the Commissioner could actually direct an individual to become a party to a unit or cooperative plan, particularly a unit plan.

Mr. WOLVERTON. Well, I am not arguing with you. I am merely attempting to get your opinion with respect to the general language contained in the bill; whether it is sufficient, without specific reference to unitization, to enable the Secretary, or the Commissioner, to direct.

Mr. SOYSTER. I am not enough of a lawyer to know how far one could go in that direction. I think that purely from an engineering standpoint it would be highly desirable to have universal unit operation of oil fields.

Mr. WOLVERTON. I sought in a general way to obtain from the witness who appeared Monday, from the Department, representing himself to be the attorney who drew the bill, to gain some knowledge as to what was possible under the bill, and I was not able to get very definite information. I have in mind to inquire of each witness to find out just how broad in scope the bill really is.

Mr. SOYSTER. Of course, I could not give you any official opinion on that subject, because my scope of authority is limited to the technical aspects of the bill, its reasonableness from the point of view as to matters of administration and policy are clearly out of my scope of authority, and I certainly would have no basis for having an opinion other than a personal one.

Mr. COLE. Mr. Soyster, you may proceed.

Mr. SOYSTER. I will proceed from where I left off, Mr. Cole.

Mr. COLE. Yes, sir.

Mr. SOYSTER. I was discussing the particular form or the forms of unit plans which have been considered by the Geological Survey.

The proponents of unit plans have been left wide discretion to devise any form of agreement which they may deem appropriate, with due regard to the variations and conditions that exist in different areas. However, the Secretary of the Interior is required to determine and certify that a plan is necessary or advisable and in the public interest, and therefore reserves the right to decide whether the agreement will accomplish the intended purposes of the law authorizing the approval of unit or cooperative plans.

In order to aid in incorporating unit plans into an acceptable form of agreement, the Acting Secretary of the Interior, on August 7, 1934, approved a specimen form of agreement submitted by the Geological Survey. A revision of this form designated "Form A, January 1936," was subsequently adopted in a similar manner. The revision of the form provides recognition of certain added benefits to holders of rights in Federal lands upon commitment of such rights to unitization, provided by the act of August 21, 1935, supra. Certain other changes were made which experience in the preparation of plans had shown were necessary or desirable.

The specimen form approved by the Department is applicable only where a single operator is vested with exclusive right to conduct and manage the operation of the unit area for the discovery and development of unitized substances. Under such form of agreement the operator must be granted the exclusive right and privilege, except as limited in the agreement, of exercising any and all rights of the parties signatory thereto or consenting thereto necessary to prospect for production and disposal of the unitized substances. The operator is granted possession of the properties involved but is not vested with title thereto. Actually, the operator usually is the owner of most, if not all, of the operating rights, but such ownership is dependent upon independent documents—that is, the operating agreement—and not upon the unit agreement.

In this connection, that is the only form which the Department ever submitted to the operators, more or less as a guide as to the specific requirements of the Department with reference to such forms of agreement. There have been other forms submitted to the Department, other types of unit plans, and also cooperative plans. For example, in the Lance Creek field in Wyoming there is a form of unit plan effective in that area; yet each of the operators or holders of operating interests operate their respective leases, but they operate and produce only to a definite allocation of the production which is made to them in accordance with the provisions of the unit agreement. So that each operator gets only his proper share of the production.

Since the individual leases are operated by their respective owners, one operator may, because of the fact that his lease is situated close to the apex of the structure, find that he has a gas cap to contend with or has high gas-oil ratio wells. Under this plan he will shut in those wells or curtail production to the extent necessary as recommended by the engineering committee which is established under the plan for the determination of the methods and the practices to be followed in that field by all the operators parties to this agreement.

If an operator overproduces his allowable, he of course receives no benefit from the amount over and above his allocation, but must turn that over to the other operators who have produced less than their allowable, and such operator as receives that oil must pay the producer of it according to the decision of the committee, the engineering committee, 25 cents a barrel as the production cost. That is a bookkeeping transaction between the companies for the purpose of adjusting, you might say, overages and underages with relation to the allocation basis provided by the plan.

In California a cooperative plan covering the Buena Vista Hills structure in part includes public-domain lands, lands of the Naval Petroleum Reserve, and some patented lands. The operators in that area were not willing to enter into a unit plan, but they did enter into a cooperative plan of development which provides for a well-spacing program and provides for consultation among the parties to the agreement as to the best methods to follow in the development and production of the properties.

With reference to cooperative plans, I would say that there are two types: The type which merely provides a well-spacing and casing program and provides for discussion of problems of mutual interest between themselves, with a committee determining what should or should not be done; but beyond this lessees take the oil that can be recovered from their respective tracts or properties. The other type of cooperative plan is that which verges close to a unit plan, one which at least has an expressed policy to the effect that it is the intent of the agreement to provide for the withdrawal of oil under the theory of correlative rights, rather than under the so-called rule or law of capture.

Since unitized operation of Federal land was authorized by the law, the Secretary of the Interior has approved 112 agreements embodying unit plans. One of these agreements was a cooperative plan involving lands in the naval petroleum reserve in California, which I just referred to, but that particular agreement also is approved by the Secretary of the Navy as well as the Secretary of the Interior. These plans include oil and gas fields having a gross area of 1,639,595 acres located in 8 States and Alaska. Approximately 81 percent of the land in the gross area is committed to the approved unit plans. In all of these plans the acreage interest committed to the agreement are controlled by the parties to the agreement and are regarded as adequate in amount and location to permit effective consummation of a logical, orderly, and reasonably comprehensive plan of development. Unfortunately, in most fields some land is owned by interests which desire to operate independently and competitively with the unitized interests, and under such conditions the unit plan cannot be made fully effective.

I might say, in diverting here for a moment, that in all unit plans there is a provision which requires the unit operator or operators to protect the unit area against damage through drainage by lands not subject to the unit agreement. So that all of the parties who are participants in the plan may be assured of fair and equitable treatment and some guaranty against loss of the resources which underlie their property on which they have, through the unit agreement, assigned their operating rights to the unit operator.

The 112 approved agreements represent the acceptable proposal submitted for fields or prospective fields out of a total of 1,667 such agreements which have been received and considered in the Geological Survey. Most of the unapproved plans were submitted prior to December 31, 1937, as prima facie compliance with the unitization requirements of permits and to obtain extensions of such permits without fulfilling the drilling requirements thereof. The majority of these agreements were regarded as not subject to approval because of defects either as to form or substance. Where the agreement was defective only as to form the proponents were informed in detail of the revisions necessary to make the agreement acceptable.

In this connection, there have been unit plans submitted for consideration which relate to areas on which there has been no discovery of oil and gas at all. There are no wells, but there may be favorable geologic information available indicating the presence of a geologic structure which may be a favorable reservoir for the accumulation of oil.

There is also the type of unit plan for areas that have been developed for a good many years, such as the Salt Creek field in Wyoming, which was recently unitized. They commenced operations in that field under the unit agreement the first of last month, I believe.

There are other areas in which unit plans have been submitted and in most cases rejected; that is, in areas where the geologic information available indicated that it was entirely unfavorable for the accumulation of oil and its storage. And in other cases where the information submitted by the proponents was purely hypothetical or conjectural, rather than actual. And in most of those cases the plans as previously stated were rejected because of that deficiency.

Valuable discoveries of oil and gas have been made in 44 of the areas unitized, and the fields involved contain estimated reserves of approximately 966 million barrels of oil, or a little more than 4½ percent of the estimated reserves of the United States. During May 1939, the public lands in these approved plans produced 1,816,637 barrels of oil, or 1.6 percent of the total production in the United States. The gas reserves in the unitized areas comprise only a fractional percentage of the total United States reserves. Unitized operations on Federal lands, therefore, represents a relatively small but nevertheless important factor in the petroleum industry. These plans have not been in operation for a sufficient period of time to furnish conclusive evidence of their particular or specific value. The experience gained by the Geological Survey demonstrates that the theory of unitization is sound. It discloses that this procedure furnishes a practicable and effective means of producing maximum obtainable yields of oil or gas from a field, of reducing waste to a minimum, lowering the cost of development and operations, and making available an adequate supply over a longer period of time, all of which constitute major factors in reducing the cost of petroleum products to the ultimate consumer.

Under the American concept of land ownership, unit operation is the key to conservation since nature ignores man-made subdivisional boundaries. Sediments are deposited and tectonic movements occur which create structural traps into which petroleum and natural gas accumulate, all without reference to these arbitrary boundaries of land ownership. If effective conservation of these natural resources is to become a reality, nature and the science of inanimate matter must be taken into account. Engineering principles based on these laws of nature cannot be applied piecemeal without relation to one another with effective results.

With the development and production of our oil and gas resources on the basis of units of accumulation—that is, geologic structures or structural traps—our large present known reserves and those yet to be discovered will not constitute a threat to more disruption due to periods of feast and famine but will make available a more constant flow of an essential commodity and the products thereof at reasonable prices. Then, too, each participant of whatever character in such plans of development and operation will receive his fair and proper share of the benefits accruing from such resources as there may then be a market for. Under such a planned order of development and operation no individual operator or landowner will suffer the loss or dissipation of the resources under his land because of his inability to market the resources capable of being produced. It is probable that in the case of most productive structures fewer wells will be necessary to obtain the maximum recovery of oil. Costs of production per barrel will generally be reduced, since the natural energy in the reservoir will be utilized in lifting the oil to the surface.

The production of these natural resources, according to sound engineering principles in the case of most flush fields, would probably result in a reduction of daily production. Therefore proration, as known to the industry today, in all probability would be unnecessary; at the same time the recoverable known reserves of petroleum would, I believe, be materially increased.

It is my personal opinion that some uniform conservation legislation of the type of the proposed legislation—H. R. 7372—is not only desirable but essential if the cupidity and the unscrupulous desires of some individuals and companies are to be subjugated to desirable and necessary action in the public interest.

Mr. COLE. Mr. Soyster, as I understand, you have reports in your possession pertaining to lands under supervision by engineers of the Survey?

Mr. SOYSTER. That is correct.

Mr. COLE. How many fields and in what States do these reports cover?

Mr. SOYSTER. If I may, I would like to read a statement I have prepared in connection with the reports which were submitted by the engineers in our organization relative to the particular fields in which they considered there was waste.

Mr. COLE. Do these reports show some definite reports of waste in those fields?

Mr. SOYSTER. Yes; they do.

Mr. COLE. All right; let us have that.

Mr. SOYSTER. The statement I have prepared more or less consolidates the several reports that were submitted by the different engineers. They were not all submitted on identically the same basis, so that some interpretation had to be made of the wastes reported by the engineers in order to tabulate them on a uniform basis.

Mr. COLE. You mean they deal with waste such as is contemplated under this bill?

Mr. SOYSTER. That is correct.

Mr. COLE. All right.

Mr. SOYSTER. Our engineers were asked the question, If this bill was actually a law, which fields would be in violation of that law because of waste.

Mr. COLE. All right.

Mr. SOYSTER. Field engineers of the Geological Survey have submitted data with reference to oil fields which in their belief or to their knowledge would be subject to citation for waste in some form or another as defined by H. R. 7372.

Of 275 producing fields considered, located in 7 States—California, Colorado, Louisiana, Montana, New Mexico, Oklahoma, and Wyoming—51, or 19 percent, are reported by the engineers as being operated in such a manner as to involve waste in some form as defined under the provisions of the proposed legislation. Of these 51 fields, 13, or 5 percent, were so reported because of the practices and methods of certain operators, while the remaining 38, or 14 percent, were so reported because of the practices and methods of operators generally.

Of the 51 fields, 21, or 8 percent, were reported because in the opinion of the engineers it was believed that waste was resulting from underground loss or dissipation due to improper casing programs which exposed an excessive amount of the productive zone or zones or because of improper production practices and methods, as well as improper rates of withdrawals. All of the 51 fields were reported by the engineers as being operated in such a manner as to constitute waste as a result of excessive gas-oil ratios, premature release of natural gas from solution in the crude oil or by blowing gas to the atmosphere before it had fulfilled its full and proper function in the production of crude oil. Therefore, 21 of the 51 fields were reported as involving both physical waste and waste of reservoir energy.

Now, with reference to that statement I would like to add that the supervisory organization of the Geological Survey has, of course, a very limited appropriation and personnel, which makes it difficult to accomplish as much under the conservation provisions of our existing mineral leasing act and its amendments as is desired. We are spread too thin to accomplish all of the aims and desires which we hope to achieve.

However, I might say here that this gas waste, so far as actual physical blowing of gas is concerned, is seldom on public lands of the United States, because in our regulations we have a provision for the payment or assessment of a penalty, you can call it that if you like, which provides that for all gas that is blown to the atmosphere there shall be a charge of 5 cents a thousand. That is not for the royalty portion of the product produced as determined by the applicable rate of royalty for that particular lease, but it applies to the full volume of gas so blown to the air. There have been a few cases where gas has been blown to the air and where that penalty has not been assessed against the operator because of the circumstances involved in the particular case, it was felt that the waste was unavoidable, that the operator did his utmost to prevent it and took prompt and diligent action to stop that waste immediately. And to date we have not billed any operators on public lands of the United States for such waste.

In California, shortly after the discovery of the Kettleman Hills field in 1928, two wells drilled there by the Continental Oil Co. had such high pressures they blew out of control for some time, or rather they were open and not closed in, and the operator contended that due to the high pressures they could not be shut in. For some time there was a considerable waste of gas and some oil; that is, more condensate than oil. Finally these wells were successfully shut in.

We have found in our 20 years' experience, both under the jurisdiction of the Bureau of Mines and the Geological Survey, that the only way compliance with the operating regulations can be obtained is by cooperation with the operators, and not taking any arbitrary attitude to the effect that only the Government representative is right.

With reference to cooperation with State conservation organizations, generally speaking our relations are of the best. However, if the State had adequate personnel to enforce the provisions of the State laws they do have, they might be of service. But there are some of these oil-producing States that have only one or two men;

Wyoming has one. And it is physically impossible for one individual to consider all of the oil activities in that State under his jurisdiction and supervision. We have aided State organizations from time to time in witnessing operations occurring on lands adjoining Federal lands where there was a direct Federal interest because of the fact that action on those lands with reference to conservation measures is of vital importance to us. One operator cannot carry on operations in a wasteful manner on a tract of land adjoining land under Federal jurisdiction without affecting such land.

Mr. Cole. With what degree of success have such attempts been made, where there is waste such as you have pictured to us today, in these 21 fields? When you found waste you tried of course to correct such condition where it adjoins the public lands?

Mr. Soyster. It is impossible to correct those in some cases. In fact, in many of these cases we have endeavored to have action taken to prohibit that waste, but for reasons which are unknown to me we are unsuccessful. That is, we take it up with the proper officials, and no action results; and you might take it up again and no action results, and then finally you decide there is no use.

Mr. Cole. If you had back of you the machinery such as this bill contemplates, then you could stop it?

Mr. Soyster. Yes, sir.

Mr. Cole. Does that conclude your statement?

Mr. Soyster. Yes, sir; unless there are any particular questions you would like to ask.

One other thing I would like to add as to my opinion of this bill—I am just expressing, now, my present opinion, and to the best of my knowledge, I do not know if my view is or is not a reflection of the view of the Interior Department or anyone else, but is just a statement of what I think about it—I do not see this bill as legislation which takes anything away from the States, but a law which will complement what they have, to support the States in the conservation activities that they consider desirable and necessary. I believe that any intelligent administrator or commissioner appointed to fill this position would cooperate fully with the States, taking full advantage of all the conservation laws of a particular State. And, as in the case of our mineral leasing operations, under the mineral leasing acts on public lands we require compliance with the State laws, but our regulations and our law goes even further than the State law; we require lessees to do more in the interests of conservation than is required under some State laws.

It seems to me that whether this bill, or some satisfactory modified form is enacted, makes little difference. I am speaking now only of the technical aspects of it, and without relation to any of the legal aspects or the policy matters or administrative matters involved.

Mr. Cole. Now, Mr. Soyster, this report you have been discussing will be filed. That is the one you would like to have filed?

Mr. Soyster. Yes, sir; that is correct.

Mr. Cole. All right, sir; thank you very much.

(The report is in full as follows:)

## PROGRESS OF UNIT OPERATION OF OIL AND GAS FIELDS INVOLVING FEDERAL LANDS

### GENERAL STATEMENT

The report of the Petroleum Investigation in 1934 contains an extended discussion of principles of unit operation of oil and gas fields. These principles are again discussed in even more extensive detail in a report entitled "Energy Resources and National Policy," issued by the National Resources Committee in January 1939, and printed by the United States Government Printing Office. The same principles have been the subject of articles in the technical journals during recent years, and such discussions are cited in the National Resources Committee report. The comprehensive presentation of the general principles of unitization being thus already available, the scope of this discussion will be limited to the work of the Geological Survey in connection with unitized operatons for the production of oil or gas from lands owned by the United States.

### LEGISLATION

Unitization of Federal oil and gas deposits was authorized by the temporary act of July 3, 1930 (46 Stat. 1007), amending secs. 17 and 27 of the Mineral Leasing Act of February 25, 1920 (41 Stat. 437). This law terminated at midnight on January 31, 1931, but was reenacted as permanent legislation in substantially identical language in the Act of March 4, 1931 (46 Stat. 1523). The act of August 21, 1935 (49 Stat. 674) further amended sec. 17 of the Mineral Leasing Act of 1920, supra, and added certain additional revisions to the unitization clauses contained in the 1931 amendment.

### REGULATIONS

General Land Office Circular No. 1252, approved June 4, 1931, contains the regulations under the act of March 4, 1931, supra, which prescribe the procedure for the preparation and submission of unitization agreements. It is therein provided that any cooperative or unit plan of operation or development of a single pool or field after discovery of oil or gas must be by agreement of all Government lessees and permittees or their representatives and the owners or lessees of the lands in private ownership or by such of these separate interests as will give effective control of production. The regulations specify the type of information which must be submitted to permit a determination by the Secretary of the Interior that a unit or cooperative plan is necessary or advisable in the public interest.

These regulations further provide that the agreement must contain a provision giving authority, limited as agreed upon and therein fixed, under which the Secretary of the Interior may alter or modify the quantity and rate of production under the plan.

Under date of April 4, 1932, regulations were issued requiring that all oil and gas prospecting permits, or extensions of previously issued permits, contain a covenant for submission of an acceptable plan for the prospecting and development as a unit of the pool, field, or area affecting the permit land.

General Land Office Circular No. 1386, approved May 7, 1936, contains the current regulations governing issuance of oil and gas permits and leases for Federal lands. Pursuant to these regulations leases now being issued contain the following covenant:

"Within 30 days of demand, to subscribe to and to operate under such reasonable cooperative or unit plan for the development and operation of the area, field, or pool embracing the lands included herein as the Secretary of the Interior may determine to be practicable and necessary or advisable, which plan shall adequately protect the rights of all parties in interest, including the United States."

On October 30, 1936, the Secretary of the Interior approved, effective November 1, 1936, uniform oil and gas operating regulations applicable to lands of the United States and to all restricted tribal and allotted Indian land, except the Osage Indian Reservation. These regulations were made effective as to public lands in the naval petroleum reserves under jurisdiction of the Navy Department by approval thereof by the Secretary of the Navy November 7, 1936. These regulations, which govern the development and production under Federal auspices of oil, gas, and casing-head or natural gasoline including propane, butane, and other hydrocarbons, are made a part of all agreements for unit or cooperative development. They thus become binding on all parties to the agreements, irrespective of land ownership.

The procedure established under the foregoing regulations makes the General Land Office the office of record as to oil and gas rights involving Federal lands and vests in the Geological Survey jurisdiction over all operations for the discovery and production of oil or gas. Unitization is a functional activity involved in the latter category, and primary responsibility for the preparation, approval, and enforcement of unitized operation rests with the Geological Survey.

### OBJECTIVES OF UNITIZATION UNDER FEDERAL STATUTES

All cooperative or unit plans approved by the Secretary of the Interior must contemplate attainment of three fundamental objectives: (1) The natural resources of the unitized area must be conserved, (2) authority to control operations and production must be vested in the Secretary of the Department having jurisdictions, and (3) the rights of all parties in interest must be protected.

*Conservation of natural resources.*—Substantially every owner of oil and gas rights is interested in conservation of his property interests. The conservation covenants in a unit agreement, therefore, generally are regarded by all signatory parties as the most cogent reason for joining a unit plan. An important step toward this objective is attained by adoption on a uniform basis throughout the unitized area of the Federal operating regulations, which are designed to result in economic and efficient production of the deposits unitized. Competitive drilling and producing operations are eliminated. A logical well-spacing program is established. The quantity and rate of production is controlled in the interest of maximum ultimate returns from operations in the field. Drainage problems are eliminated or reduced to a minimum. Production of wells with an excess of gas-oil ratio is prevented. Repressuring and other secondary methods of recovery are made possible. These and other engineering problems cannot be solved without some form of unitization under the existing theory of American jurisprudence applicable to oil and gas, which holds, under the law of capture, that such deposits may be mined by any surface owner without regard to the necessity of cooperation with adjoining owners.

*Control of operations.*—The law authorizing approval of unit or cooperative agreements in which Federal land is involved requires that provision must be included in such agreements "whereby authority, limited as therein provided, is vested in the Secretary of the Department or Departments having jurisdiction over such land to alter or modify from time to time, in his discretion, the rate of prospecting and development and the quantity and rate of production" from the unitized land. The precise effect of this provision of the law has not been determined for the reason that a necessity for the direct exercise of the authority has not arisen. It is contemplated that the Federal Government shall cooperate in any reasonable restrictions that may be necessary or advisable in the public interest, whether such restrictions are imposed under the police power of the States or are voluntarily adopted by the oil and gas operators of any region. In the unit plans heretofore approved it has been customary to specify that production and disposal of the unitized products shall be in conformity with allocations, allotments, and quotas made or fixed by any duly authorized person or regulatory body under any Federal or State statute. It is further specified that the authority is limited to alteration or modification in the public interest and that the purpose and public interest to be served must be stated in any order of alteration or modification.

*Protection of rights.*—Determination of the identity of all parties in interest in a proposed unit plan is an essential prerequisite to the consummation of an agreement embodying such plan and every proponent of a unit plan involving Federal land is required to furnish sufficiently complete information to permit the various interests to be identified. Usually such interests consist of the working or operating interests that are disposed of and the royalty interests that are retained when the owner of the oil and gas rights authorizes development thereof by an oil and gas lessee or operator. As to Federal land, the General Land Office is the office of record of all such rights. For State and private lands, the offices of record in the several States must be carefully explored. In addition to the working and royalty interests, so-called overriding royalty interests are created by assignment of interests in royalty agreements. These overriding royalty interests usually rest upon the basic royalty agreement. Therefore, any unit agreement which adequately protects the basic royalty rights is regarded as adequate to protect the overriding royalty rights. In substance, protection of the rights established by the terms of a basic lease of lands or deposits will protect, so far as practicable in a unit agreement, all parties in interest.

A proper determination of the unit area is also required to adequately protect the rights of all parties in interest. Such determination must be predicated on information available as to the areal extent of the field or pool proposed for unitization. In advance of exploratory well drilling, geologic inference often can be used to show the probable limits of any single field. It is imperative, however, that such determination shall include all of one field and shall not impinge upon or overlap any adjoining field, for Federal law authorizes unitization of "a single oil or gas pool or field" with a view to avoiding monopolistic operations in a group of many fields.

Every unit or cooperative agreement should clearly indicate the intention of all parties thereto concerning the payment of costs and the allocation of benefits. These items are prorated on some equitable basis which must be prescribed in the agreement. In wildcat areas it is customary to provide that every acre of unitized land subsequently determined to be underlain by valuable deposits of oil or gas is of identical value. This situation may not exist. Certain parts of the same field may prove materially more valuable than other parts. In advance of a determination of the variations in underground conditions all interests may be willing to agree to share alike in accepting the risk of gain or loss which might result from independent operation of their lands. Where warranted by available information some other equitable basis of allocating benefits may be adopted.

## FORMS OF UNIT PLANS

The proponents of unit plans have been left full discretion to devise any form of agreement which they might deem acceptable, with due regard to the variations in conditions that exist in different areas. However, the Secretary of the Interior is required to determine and certify that the plan is necessary or advisable in the public interest and therefore reserves the right to decide whether the agreement will accomplish the intended purposes of the law authorizing approval of unit plans.

In order to aid in incorporating unit plans into an acceptable form of agreement, the Acting Secretary of the Interior on August 7, 1934, approved a specimen form of agreement submitted by the Geological Survey. A revision of this form, designated "Form A, January 1936," was subsequently adopted in a similar manner. The revision of the form provided recognition of certain added benefits to holders of rights in Federal lands upon commitment of such rights to unitization, provided by the act of August 21, 1935, supra. Certain other changes were made which experience in the preparation of plans had shown were necessary or desirable.

The specimen forms approved by the Department are applicable only where a single operator is vested with exclusive right to conduct and manage the operation of the unit area for the discovery and development of unitized substances. Under such form of agreement the operator must be granted the exclusive right and privilege, except as limited in the agreement, of exercizing any and all rights of the parties signatory thereto or consenting thereto necessary to prospect for, produce, and dispose of unitized substances. The operator is granted possession of the properties involved but is not vested with title thereto. Actually, the operator usually is the owner of most, if not all, of the operating rights, but such ownership is dependent upon independent documents and not upon the unit agreement.

Another form of agreement for unitized operation of an oil or gas field which has been accepted by the Secretary of the Interior is the so-called cooperative unit plan. This procedure is adopted in fields where there are two or more operating interests that are unwilling to select a single operator for the entire field. It then becomes necessary to seek a formula for development and production of the various interests separately and independently but subject to mutual restrictions that will result in adoption of sound engineering principles and practices.

Occasions have arisen in which small contiguous tracts of Indian lands underlain with valuable deposits of oil or gas are located in a field where a well-spacing program is in force and effect which precludes separate drilling of such tracts, or some other good and sufficient reason exists for not drilling the tracts separately. Under these conditions the interests in the separate tracts may sign a communitization lease, effective upon approval by the Secretary of the Interior, whereby the separate tracts can be developed and operated as a single unit with costs and benefits usually allocated on an acreage basis to the holders of interests in the communitized area. These leases have the aspects of a unit agreement insofar as operations on the leasehold are involved. They do not in general cover the whole of a single field or pool and operations thereunder are in competition with operations on adjoining land in the same field. Such leases are of primary interest in the present discussion as illustrating a procedure which, while lacking in the benefits obtainable under complete unitization, nevertheless, discloses that under stress of adverse operating conditions small owners of oil and gas rights voluntarily adopt unit operation for protection of their property rights.

### PROGRESS ON UNITIZATION

Since unitized operation of Federal land was authorized by law the Secretary of the Interior has approved 112 agreements embodying unit plans. One of these agreements involved land in naval petroleum reserves which was also approved by the Secretary of the Navy. These plans include oil and gas fields having a gross area of 1,639,593 acres located in eight States and Alaska. Approximately 81 percent of the land in the gross area is committed to the approved unit plans. In all of these plans the acreage interests committeed to the agreement or controlled by parties to the agreement are regarded as adequate in amount and location to permit effective consummation of a logical, orderly, and reasonably comprehensive plan of development. Unfortunately, in most fields some land is owned by interests which desire to operate independently and competitively with the unitized interests, and under such conditions the unit plan cannot be made fully effective.

The 112 approved agreements represent the acceptable proposals submitted for fields or prospective fields out of a total of 1,667 such agreements which have received consideration. Most of the unapproved plans were submitted prior to December 31, 1937, as prima facie compliance with the unitization requirements of permits and to obtain extensions of such permits without fulfilling the drilling requirements thereof. The majority of these agreements were regarded as not subject to approval because of defects either as to form or substance.

Where the agreement was defective only as to form the proponents were informed in detail of the revisions necessary to make an acceptable agreement. Generally where the land was regarded as of sufficient value to warrant early exploratory drilling the revised agreement was submitted with considerable promptitude. Otherwise the proponent has allowed the agreement to lapse by inaction.

The chief defects of substance which render a unit agreement unacceptable are proposals submitted for areas in which effective control is lacking, in which conditions governing the origin and accumulation of oil or gas in commercial quantity are unfavorable or indeterminate from the available information, or in which wells have been drilled which tend to establish that the oil and gas possibilities are purely conjectural, tenuous, or hypothetical. Under such conditions unitization may be regarded as neither necessary nor desirable in the public interest and the plans rejected. However, the conditions involved in each individual case must be carefully considered.

Table 1 contains a summary, by States, of the 112 approved unit plans. Valuable discoveries of oil or gas have been made in 44 of the areas, and the fields involved contain estimated reserves of 965,991,011 barrels of oil, or 5.6 percent of the estimated reserves in the United States. During May 1939 the public lands in these approved plans produced 1,816,637 barrels of oil, or 1.6 percent of the total production in the United States. The gas reserves in unitized areas comprise a fractional percent of the total United States reserves.

Unitized operations on Federal lands, therefore, represent a relatively small but nevertless important factor in the national program of oil and gas activities. They have not been in progress for a sufficient period to furnish conclusive evidence of their value. The experience gained by the Geological Survey demonstrates that the theory of unitization is sound. It discloses that this procedure furnishes a practicable and effective means of producing maximum obtainable yields of oil or gas from a field, of reducing waste to a minimum, of restricting production to market requirements, and of lowering the cost of development and operations, all of which constitute a major factor in reducing the cost of petroleum products to the ultimate consumer. All of these benefits are urgently desired by the Nation and are recognized by the oil and gas operators as essential to the stability of their business. They cannot be fully realized throughout the public domain region because the Federal lands containing valuable deposits of oil or gas generally lie in fields where unitization is effectively prevented by private landowners who are unwilling to commit their lands to a unit plan.

TABLE 1.—*Summary of data on unit and cooperative agreements approved by the Secretary of the Interior*

| State | Number of approved unit agreements | Unit area acres | Percent of unit area committed to unit agreement | Monthly production, public lands of unit area, May 1939 | Monthly production barrels of oil, for State, May 1939 | Percent production, barrels of oil, unit area of State's production |
|---|---|---|---|---|---|---|
| Alaska | 6 | 216,466 | 76 | 0 | 0 | 0 |
| California | 14 | 161,576 | 54 | 1,008,766 | 19,074,000 | 5.3 |
| Colorado | 15 | 185,520 | 77 | 9,870 | 132,000 | 7.5 |
| Montana | 10 | 150,695 | 89 | 0 | 508,000 | ---------- |
| New Mexico | 6 | 48,754 | 77 | 2,695 | 3,318,000 | 0.08 |
| Oklahoma | 2 | 11,698 | 97 | 190,057 | 14,811,000 | 1.3 |
| South Dakota | 1 | 3,009 | 80 | 0 | 0 | 0 |
| Utah | 14 | 442,206 | 86 | 0 | 0 | 0 |
| Wyoming | 44 | 419,769 | 88 | 605,249 | 1,908,000 | 31.7 |
| Other States | 0 | 0 | 0 | 0 | 70,790,000 | ---------- |
| Total | 112 | 1,639,593 | 81 | 1,816,637 | 110,541,000 | 1.6 |

| State | Estimated reserves, barrels of oil, unit area, Jan. 1, 1939 | Estimated reserves, barrels of oil, all fields, Jan. 1, 1939 | Percent reserves, barrels of oil, unit area of each State | Percent reserves, barrels of oil, each State of United States, total | Percent reserves, barrels of oil, unit area of United States, total |
|---|---|---|---|---|---|
| Alaska | 0 | 0 | 0 | 0 | 0 |
| California | 745,642,740 | 3,188,763,000 | 23 | 18 | 4.3 |
| Colorado | 7,500,000 | 17,713,000 | 42 | 0.1 | 0.04 |
| Montana | 2,240,000 | 104,471,000 | 2 | 6 | 0.01 |
| New Mexico | 4,038,951 | 703,252,000 | 0.6 | 4 | 0.02 |
| Oklahoma | 79,491,120 | 1,162,370,000 | 7 | 7 | 0.46 |
| South Dakota | 0 | 0 | 0 | 0 | 0 |
| Utah | 0 | 0 | 0 | 0 | 0 |
| Wyoming | 127,078,200 | 261,133,000 | 49 | 2 | 0.73 |
| Other States | 0 | 11,910.444,000 | 0 | 63 | 0 |
| Total | 965,991,011 | 17,348,146,000 | ---------- | 100 | 5.6 |

The 6 public-land States having approved unit plans or cooperative agreements in effect have 965,991.011 barrels of oil reserves under the lands embraced in such plans, or 18 percent of the reserves of 5,437,702,000 barrels for the 6 States on Jan. 1, 1939.

During May 1939, the public lands within unit areas produced 1,816,637 barrels of oil, or 1.6 percent of the United States total of 110,541,000 barrels for that month, or 4.6 percent of the total production of 39,751,000 barrels of oil from the 6 public-land States having approved unit plans.

During May 1939, all public lands produced 3,530,059 barrels of oil, of which 1,816,637, or 51.5 percent, was produced from public lands within a unitized area.

## PUBLIC AND INDIAN PETROLEUM LANDS

### OIL AND GAS LEASES ON THE PUBLIC DOMAIN

Since the committee's report in 1934, the Congress has enacted legislation amending the basic oil and gas leasing act of February 25, 1920 (41 Stat. 437), which is of paramount importance in the conservation of the Nation's oil and gas resources on the public domain. The legislation referred to is the act of August 21, 1935 (49 Stat. 674), sometimes hereinafter called the amendatory act. That act made certain fundamental changes in the method of disposing of the oil and gas deposits on the public domain so as to provide for a more businesslike development of these important natural resources and a return to the United States of a royalty commensurate with the royalty customarily paid under oil and gas leases on State and privately owned land. These changes are hereinafter discussed under appropriate headings.

*Prospecting on the public domain.*—The 1920 act authorized the Secretary of the Interior to issue permits for a period of 2 years to prospect for oil and gas. Upon making a valuable discovery, the holder of the permit was entitled to a lease for one-fourth of the area embraced in the permit, usually the most productive lands, at a small royalty of 5 percent to the United States. This low royalty rate was offered as an inducement to prospectors in order to encourage the exploration and development of the oil and gas resources on the public lands. Under the permit system the prospector could prospect his land for 2 or more years without payment of any rental or other holding charge prior to making a valuable discovery of oil or gas. It became apparent after 15 years that the special inducements offered to prospectors in the 1920 act were no longer justified. Conditions in the oil industry and the need for conserving these valuable resources resulted in the amendment of the 1920 act. The amendatory act abolished the system of issuing prospecting permits and substituted therefor a new policy of issuing leases to prospect for oil and gas on the public domain. To assure bona fide prospecting it provided for the payment in advance of a rental of not less than 25 cents per acre per annum. It increased the royalty payable to the United States upon a discovery of oil or gas to a minimum of 12½ percent to conform to the rate of royalty paid on State and privately owned lands. In short its purpose, among other objectives, was to insure an adequate return to the United States of its rightful share of the value of the oil and gas produced from the public lands.

The amendatory act made appropriate provision for the protection of the holders of outstanding permits which were issued under the 1920 act. Under its terms, a majority of the outstanding permits were extended to December 31, 1937, and the Secretary of the Interior was authorized, upon a proper showing that diligence had been exercised, to extend any of those permits, or the remaining permits which had not received a statutory extension, for a period not beyond December 31, 1938. The act of August 26, 1937 (50 Stat. 842), prolonged the life of the permit system by extending to December 31, 1939, certain oil and gas prospecting permits which were outstanding on December 31, 1937, and which on that date fell within one of the classes of permits described in the act. In pursuance, however, of the national policy expressed in the amendatory act to abolish the system of issuing prospecting permits, the date, December 31, 1939, fixed in the act of August 26, 1937, definitely established the end of the permit system.

*Leases at competitive bidding.*—Section 17 of the leasing act as amended by the act of August 21, 1935, provides, in part, for the leasing of lands in units of not exceeding 640 acres each, which shall be as nearly compact in form as possible, at a stated royalty and rental to the highest responsible qualified bidder by competitive bidding. In practice, this provision has been applied only to lands within the known geologic structure of a producing oil or gas field. By regulation, the Secretary of the Interior has prescribed for such lands a royalty rate scale ranging from 12½ to 32 percent depending upon the amount of production, and an annual rental of $1 per acre, such rental paid for any one lease year to be credited against the royalties as they accrue for that year. The established policy of the Department of the Interior is not to offer land within the known geologic structure of a producing field for lease unless actual or threatened drainage of the oil and gas deposits owned by the United States exists by virtue of producing wells on adjoining or nearby privately owned land.

*Leases without competitive bidding.*—Leases without competitive bidding are issued on applications filed therefor to applicants qualified under the amendatory act for lands not within any known geologic structure of a producing oil or gas field. The amendatory act provides for the payment in advance of a rental to be fixed in the lease of not less than 25 cents per acre per annum. By regulation, the Secretary of the Interior has prescribed an annual rental of 50 cents per acre for the first year of the lease and an annual rental of 25 cents per acre for the second and each succeeding lease year until oil or gas in commercial quantities is discovered on the leased lands. Thereafter, beginning with the first lease year succeeding discovery, the annual rental is $1 per acre, such rental paid for any one lease year to be credited against the royalties as they accrue for that year. The rate of royalty prescribed in leases issued without competitive bidding is 12½ to 32 percent, depending upon the amount of production.

*Lease tenure.*—Under the 1920 act, oil and gas leases issued for a period of 20 years with a preference right of renewal for successive periods of 10 years on such reasonable terms and conditions as the Secretary of the Interior might impose. Notwithstanding that the law gives adequate assurance of the renewal of leases on reasonable terms and conditions, the lessees naturally attempt to produce as much oil or gas during the first 20-year period as they can. The amendatory act has made a definite contribution to the interests of conservation in this matter of lease tenure. Under that act leases are issued for a period of 5 years and so long thereafter as oil or gas is produced in paying quantities for unproven oil and gas lands, and for a period of 10 years and so long thereafter as oil or gas is produced in paying quantities when the lands to be leased are within a known geological structure of a producing oil or gas field. The amendatory act provides further that no such lease shall be deemed to expire by reasons of suspension of prospecting, drilling, or production pursuant to any order or consent of the Secretary. Because of the change in the lease tenure, a lessee may adjust his rate of production to the market demand without fear of loss. Lessees holding 20-year leases under the 1920 act are encouraged under the amendatory act to submit for the approval of the Secretary a cooperative or unit plan of development affecting their leases by providing that such leases shall continue in force beyond their initial 20-year period until the termination of such plan.

*Unit or cooperative development.*—As a conservation measure, the amendatory act will undoubtedly have far-reaching effect in conserving the irreplaceable oil and gas resources on the public domain. It vests in the Secretary of the Interior the power to require the development and production of the oil and gas deposits under such unit or cooperative plan of development as he may deem necessary in the public interest. In contrast with the acts of July 3, 1930, and March 4, 1931, which authorize the Secretary of the Interior, with the consent of the holders of the permits and leases involved, to approve a unit or cooperative plan of development for any single oil or gas pool or field, the amendatory act empowers the Secretary to require that all leases thereafter issued be conditioned upon an agreement by the lessee to operate under such reasonable cooperative or unit plan for the development and operation of the area, field, or pool as the Secretary may determine to be practicable and necessary or advisable. In addition to the authority vested in the Secretary by the 1931 act to alter or modify from time to time in his discretion the quantity and rate of production under any unit or cooperative plan of development, the amendatory act vests in the Secretary authority to alter or modify from time to time in his discretion the rate of prospecting and development under any such plan. With authority thus vested in the Secretary of the Interior to supervise oil and gas development on the public domain it is evident that wasteful practices will not be permitted to flourish.

*Exchange provisions of the amendatory act.*—The amendatory act expressly granted to the holders of valid outstanding oil and gas prospecting permits the right, prior to the expiration date of any such permit, to exchange the same for a lease at a royalty of not less than 12½ percent. Out of some 8,000 prospecting permits which were eligible for such exchange it is estimated that the holders of approximately 5,000 permits filed timely applications to exchange them for leases.

Under the provisions of the amendatory act of the Secretary of the Interior is authorized to issue new leases at a royalty rate of not less than 12½ percent in exchange for outstanding oil and gas leases which were issued under the 1920 act. The new leases offer decided advantages to the lessee. They provide an indeterminate lease term, the life of an exchange lease running for as long as oil or gas is produced in paying quantities, and they provide for the payment of royalties to the United States which as a whole are slightly lower than the royalties required to be paid under the old leases. In return, the new leases vest in the Secretary greater control over the operations of the lessee and assure the development and production of the oil and gas deposits in accordance with sound conservational practices.

*Acreage limitations.*—To encourage and induce the holders of leases to operate under such reasonable cooperative or unit plan for the development of an area, field, or pool as the Secretary may determine to be practicable and necessary or advisable, the amendatory act provides that all leases operated under a plan approved or prescribed by the Secretary shall not be subject to the acreage limitations prescribed by section 27 of the leasing act, as amended.

*Compensatory royalty agreements.*—To protect the United States from loss of oil or gas through drainage the amendatory act authorizes and empowers the Secretary of the Interior, whenever it appears that wells drilled upon lands not owned by the United States are draining oil or gas from lands or deposits owned in whole or in part by the United States, to negotiate agreements whereby the United States or the United States and its permittees, lessees, or grantees shall be compensated for such drainage, such agreements to be made with the consent of the permittees and lessees affected thereby.

*Rights-of-way for pipe lines.*—The 1920 act granted to any applicant possessing the qualifications prescribed in section 1 of the act a right-of-way through public lands of the United States, including national forests, for pipe-line purposes for the transportation of oil or natural gas, on condition that the pipe line shall be operated and maintained as a common carrier. That act in itself constituted a statutory grant of rights-of-way for pipe-line purposes. The act of August 21, 1935, amended the 1920 act by vesting in the Secretary of the Interior discretionary authority to grant rights-of-way for pipe-line purposes. In addition to the conditions provided in the 1920 act, under the terms of the amendatory act, the grant is made subject to the express condition that such pipe lines "shall accept, convey, transport, or purchase without discrimination oil or natural gas produced from Government lands in the vicinity of the pipe line in such proportionate amounts as the Secretary of the Interior may, after a full hearing with due notice thereof to the interested parties and a proper finding of facts, determine to be reasonable."

### PETROLEUM LEASES ON INDIAN LANDS

Beginning with the formation of the Federal Government it has been its policy as guardian of the dependent Indian tribes and individual Indians to protect their assets and to assist them in making use of them. This policy extends to the leasing of the Indian lands for oil and gas production under specific acts of Congress conferring jurisdiction upon the Interior Department to lease the lands and to promulgate regulations governing the leases and all operations under them.

The disposal of oil and gas under mineral leases falls into two classes according to the ownership of the lands. In one class are lands held by tribes in communal ownership. This includes the tribal lands which have never been allotted to individual Indians and also the minerals under lands which have been allotted with a reservation of mineral rights to the tribe. Tribal lands often lie in large bodies and are leased by the Tribal Council with the approval of the Secretary of the Interior. All receipts from the leases accrue to the tribe. The other class is composed of lands which have been allotted to individual Indians without a reservation to the tribe (or to the United States in the case of public-domain allotments) of the minerals. This class for practical purposes in connection with oil and gas development is much the same as lands owned by white citizens. Many of the Indian reservations which have been allotted, particularly in Oklahoma where most of the Indian oil lands are located, have been completely broken up by allotment, and due to sales of allotted lands are now interspersed with white-owned lands. Leases on allotted lands are executed by the allottees, or if they are decreased by their heirs or devisees and are approved by the Secretary of the Interior. The royalty and rental receipts from allotted lands accrue to the Indian owner or owners.

Until 1925 many leases were made through private negotiations with applicants. Since that time leases have been sold to the highest responsible bidder at public auction or by sealed bids for a bonus consideration in addition to the rentals and royalties stipulated in the lease.

Generally the rate of royalty prescribed in Indian leases is 12½ percent of the gross receipts from the sale of the products. On the Osage Reservation in Oklahoma the rate is one-sixth with the further provision that if all the wells on any quarter section produce an average of more than 100 barrels daily per month the rate shall be one-fifth. The rate under the south Burbank unit lease, which involves a pressure maintenance plan, is 17½ percent. The leases provide for an annual rental of $1.25 per acre which may be credited against the royalty on production for the year in which paid.

Most Indian leases are made for 10 years (at Osage 5 years) and as much longer thereafter as oil and gas is produced in paying quantities.

Prior to 1933, several lease forms were in use. A lease form (5–154h) was approved in 1933, which was revised in March 1937, for general use in the leasing of allotted lands, and a similar form (5–157) was approved in June 1939, for use in connection with tribal lands except on the Osage, Blackfeet, and

Crow Reservations, and the surplus Wind River lands, where special forms of leases are used.

The leases grant the Secretary of the Interior the right to require the lessee to drill all wells necessary in the diligent development of the property or in lieu thereof to require a payment of not to exceed $1 per acre per annum after the first year of the lease. Stricter drilling requirements are inserted in some instances, particularly on the Blackfeet Indian Reservation in Montana, where some leases have required the lessee to drill one or two wells each year until as many wells have been drilled as there are 40-acre tracts in the lease. In States having oil proration laws, the oil lessees comply with valid State laws and regulations. The following provisions relating to the control of oil production are included in the lease forms:

"*Provided*, That the right to drill and produce such other wells shall be subject to any system of well spacing or production allotments authorized and approved under applicable law or regulations, approved by the Secretary of the Interior and affecting the field or area in which the leased lands are situated" (excerpt from sec. 3 (b) (1), Forms 5–154h and 5–157).

"DRILLING AND PRODUCING RESTRICTIONS.—It is covenanted and agreed that the Secretary of the Interior may impose restrictions as to time or times for the drilling of wells and as to the production from any well or wells drilled when in his judgment such action may be necessary or proper for the protection of the natural resources of the leased land and the interests of the Indian lessor, and in the exercise of his judgment the Secretary may take into consideration, among other things, Federal laws, State laws, or regulations by competent Federal or State authorities or lawful agreements among operators regulating either drilling or production, or both" (sec. 8, Form 5–157, and sec. 10, Form 5–154h).

"UNIT OPERATION.—The parties hereto agree to subscribe to and abide by any agreement for the cooperative or unit development of the field or area, affecting the leased lands, or any pool thereof, if and when collectively adopted by a majority operating interest therein and approved by the Secretary of the Interior, during the period of supervision" (sec. 9, Form 5–157, and sec. 11, Form 5–154h).

On allotted lands the sale of leases is governed primarily by the demand for them. Sales are held as applications for leases are received. On tribal lands since 1929, an effort has been made to conserve the assets of the Indians as much as possible and leases are offered for sale only to prevent drainage or when it is considered there is a real market demand for them and the additional production which may result will not have a depressing effect upon the market. At Osage the act of March 3, 1921 (41 Stat. 1249), required the annual offering for oil leasing of approximately 100,000 acres. This was changed by the act of March 2, 1929 (45 Stat. 1478), which provides that not less than 25,000 acres shall be offered annually. It has not been found advisable in recent years to offer more than this amount and leases have not been sold on all of the lands offered.

The laws authorizing the leasing of Indian lands for oil and gas mining are as follows:

Tribal lands (except Osage and Crow Reservations and ceded Wind River lands): Act of May 11, 1938 (52 Stat. 347).

Allotted lands (except in the Five Civilized Tribes): Act of March 3, 1909 (35 Stat. 781).

Indian agency and school lands: Act of April 17, 1926 (44 Stat. 300).

Reserved lands, Fort Peck and Blackfeet Reservations: Act of September 20, 1922 (42 Stat. 857).

Osage Reservation, Okla.: Section 3 of the act of June 28, 1906 (34 Stat. 539–543); sections 1 and 2 of the act of March 3, 1921 (41 Stat. 1249); section 1 of the act of March 2, 1929 (45 Stat. 1478); section 3 of the act of June 24, 1939 (52 Stat. 1034).

Crow Reservation: Section 6 of the act of June 4, 1920 (41 Stat. 751–3), as amended by the act of May 26, 1926 (44 Stat. 658); section 2 of the act of May 19, 1926 (44 Stat. 566).

Ceded Wind River lands: Act of August 21, 1916 (39 Stat. 519).

Five Civilized Tribes allotted lands: Section 2 of the act of May 27, 1908 (35 Stat. 312).

Addition to the Navajo Reservation: Act of March 1, 1933 (47 Stat. 1418).

### PREVENTION OF AVOIDABLE WASTE ON PUBLIC AND INDIAN LANDS (EXCEPT OSAGE RESERVATION) AND THE EXTENT TO WHICH RESULTS ARE AFFECTED BY PRIVATE OPERATIONS ON CONTIGUOUS NONFEDERAL LEASES

The Geological Survey, acting within decided limitations on personnel and appropriations, makes every possible effort to prevent avoidable waste through enforcement of the Mineral Leasing Act and of the operating regulations applicable to oil and gas operations on public domain, naval petroleum reserve, and Indian lands; and through cooperative and missionary work with respect to the activities of operators on contiguous non-Federal, State, and private leases.

The oil and gas supervisory operations of the Geological Survey are effected through the agency of 16 field offices and suboffices, located strategically throughout the public land States. The engineering activities of the various offices are directed to the application of improved recovery methods and to increased ultimate recovery of oil and gas. Close cooperation on individual well studies and on experimental work between the operators and the Survey engineers has been productive of results which promise to give much greater ultimate recovery of oil and gas than could have been anticipated under ordinary producing conditions. Definite uniform casing programs for specific areas have been evolved to which all drilling operations on public lands are required to conform, and many experimental repairs to reduce or eliminate water production, increase oil production and, above all, to restrict unnecessary gas production, have been conducted after appropriate study of the wells had been made. Testing, experimenting, and repairing have disclosed the practicability of the procedure evolved and, in addition, have substantiated the contention of the Survey engineers that accurate and complete well records are one of the most necessary items for the determination of a proper repair procedure.

The underlying principle followed is that of giving assistance to and cooperating with operators, thereby reducing to a minimum the necessity for making requirements and issuing orders. The steps taken to prevent avoidable waste are described hereinafter under appropriate headings.

In some cases attempt is made to show the benefits gained in dollars and cents as a practical demonstration of the dividends which accrue from the adoption of prudent conservation measures and policies leading to the prevention of waste of crude oil and associated hydrocarbons. But it must be borne in mind that, out of the innumerable efforts toward conservation being made by officers of the Federal Government in connection with operations on lands under their jurisdiction, there are comparatively few cases in which the savings and avoidance of loss can be wholly, or even in part, immediately reduced or translated to a cash value. In all such efforts, when successful, the principles of engineering point to benfits resulting from wise conservation measures which may be proved years hence by the technical historians to have been of inestimable value.

1. *Control over the location, spacing, drilling, completion, and production of wells to prevent loss of reservoir energy.*—Prevention of avoidable physical waste of crude oil and associated hydrocarbons initiates with control over the location and spacing of oil and gas wells. Wells located improperly in the light of available expert geological and engineering data often result in failures, representing a waste of investment which, if prevented, could be more profitably utilized in operations promising a reasonable opportunity for success in new discovery or in the promotion of secondary recovery methods in proven but declining fields. Crowded well locations represent not only a wasteful expenditure of drilling money, but result in the premature depletion of natural resources sought to be recovered and in the early dissipation of natural forces vital to the most efficient and most inexpensive recovery of such resources.

Section 16 of the Mineral Leasing Act of February 25, 1920 (41 Stat. 443), provides that all permits and leases of lands containing oil or gas made or issued under the provisions of said act shall be subject to the condition that no wells shall be drilled within 200 feet of any of the outer boundaries of the lands so permitted or leased unless the adjoining lands have been patented, or title thereto otherwise vested in a private owner, and to the further condition that the permittee or lessee will, in conducting his explorations and mining operations, use all reasonable precautions to prevent waste of oil or gas developed in the land or the entrance of water, through wells drilled by him, to the oil sands or oil-bearing strata to the destruction or injury of the oil deposits. The act provides that violations of these provisions shall constitute grounds for the forfeiture of the permit or lease. The operating regulations contain essentially the same provisions.

Before commencing any operations, the lessee is required to submit to the oil and gas supervisor in charge an adequate well-spacing and well-casing program and obtain his approval thereof. With the consent and approval of the supervisor, the program may be modified from time to time as conditions warrant. Well spacing consistent with good oil-field practice is required in connection with oil and gas operations under the jurisdiction of the Geological Survey, and State statutes and regulations governing such matters are adopted and made applicable to operations wherever desirable or feasible. The establishment of a proper well-casing program is one of the most important essentials for the prevention of physical waste of the oil and gas resources.

It is also essential that casing programs provide for the prevention of damage to coal measures, domestic water, and other mineral deposits.

Unitized operations are encouraged by the Federal Government whenever it is deemed to be necessary or advisable in the public interest. A proper well-spacing and well-casing program is one of the fundamental requirements of an acceptable unit plan.

A concrete example of the importance of proper well location may be cited here. An operator on a Government permit requested the opinion of Survey engineers regarding the probability of obtaining production at a location where a well had been started. From the general knowledge of the stratigraphy of the area and from information obtained in one day of field investigation it was conclusively shown that the well was poorly located structurally and was drilling in strata dipping so steeply that it would be impossible for the well to reach possible oil-bearing beds. Consequently, drilling was suspended and as the company had planned to drill at least to 4,000 feet, it is estimated that a useless expenditure of from $10,000 to $15,000 was avoided.

Cores and samples from drilling wells are examined and electrical logs are studied in order to determine proper casing points, detect barren zones or zones containing water, obtain information which leads to the completion of economically productive wells, and to minimize losses from premature water flooding. Where deemed appropriate, lessees are required to take and test adequate samples to determine the presence or waste of water, the quantity and quality of water, and the amount of deviation of any well from the vertical.

The lessee is not authorized to drill, redrill, deepen, plug back, shoot, or plug and abandon any well, make water shut-off or formation tests, alter the casing, stimulate production by vacuum, acid, gas, air, or water injection, change the method of recovering production, or use any formation or well for gas storage or water disposal, without first notifying the supervisor or the supervisor's representative of his plan or intention and receiving approval prior to commencing the contemplated work. Applications to do mechanical work on wells located on public land are considered in the light of the casing programs which may be involved and approval to do such work is granted only where it appears that the casing to be used will adequately prevent waste or damage.

Lessees are expected to drill diligently and produce continuously from such wells as are necessary to protect the lessor from loss by reason of drainage or, in lieu thereof, with the consent of the lessor, to pay a sum estimated to reimburse the lessor for such loss of royalty. Consent to substitute such drainage royalty for drilling is not given in those cases where failure to drill and produce cannot be compensated for adequately in terms of money and would result in damage or loss to the formations underlying the leasehold.

2. *Prevention of loss of natural gas by escape or wasteful burning.*—Through the cooperative efforts of the Geological Survey the wastage of unmarketable sour gas in a certain field in Wyoming has been reduced by encouraging the operators to mix this gas with sweet gas to produce a usable fuel. In two other Wyoming fields an effort is being made to reduce the amount of sour gas being blown to the atmosphere. Excess sour gas produced in another field, now under unit operation, is being stored in sands situated in an isolated fault block. In still another Wyoming field one operator has shown excellent cooperation by making extensive experiments to conserve sour gas which was formerly blown to the air. This gas is now mixed with sweet gas and piped considerable distances and used for firing boilers at drilling wells.

Through the efforts of the Geological Survey many of the old wells located in a Wyoming black oil field have been, and others are now being, mudded in to prevent possible surface leaks or loss of oil into barren formations. Gas leaks in certain other Wyoming gas fields have been regularly pointed out to the operators as they occur, and success has been experienced in having these leaks repaired. In one gas field the operator, at the Survey's suggestion, has tubed the gas wells and has ceased to flow a water well by gas lift. Wastage of gas in one of Wyoming's largest and oldest oil and gas fields is usually remedied at once by corrective work and repairs when the defects are brought to the attention of the operators.

Certain areas in two California fields produce oil with natural gas containing a large percentage of carbon dioxide which so lowers its heating value as to make it unsuitable for commercial fuel. Because of a lack of market from 1,000,000 to 4,000,000 cubic feet of this gas was daily blown to the air. The various operators on both Government and private lands, the natural gasoline-manufacturing plants, and pipe-line companies entered into an arrangement by which the gas was run into the fuel systems of the gasoline plants to reach other parts of the fields where it was delivered as lease fuel in exchange for marketable gas available at other plant discharges. While it was not the sole originator of the gas-exchange plan, considerable work was done by the Geological Survey in ironing out the difficulties naturally attached to a plan involving so many operators. During the operation of the plan the savings resulting from the beneficial use of gas of low British thermal unit content, a large portion of which would otherwise have been blown to the air, has sometimes netted over $30,000 a year.

The foregoing are only a few examples of many instances in which steps have been taken to prevent the loss of natural gas by escape or wasteful burning.

3. *Prevention of loss by evaporation, exposure, or wasteful burning of crude oil.*—The operating regulations require the lessee to prevent any oil or gas well from blowing open, and in the event a well does blow open to take immediate steps and exercise due diligence to bring under control any "wild" or burning oil or gas well or water well.

All production run from leased Government lands must be gaged or measured according to methods approved by the supervisor or his representative. The lessee must provide tanks suitable for containing and measuring accurately all crude oil produced from the wells and must furnish the supervisor or his representatives acceptable copies of all tank tables. Meters for measuring oil must be first approved by the supervisor, and tests of their accuracy must be made when directed by that official. The lessee must not, except during an emergency, in which case the special permission of the supervisor must be confirmed in writing, permit oil to be stored in earthen reservoirs or in other receptacles from which there may be undue waste of oil.

In a certain district in Oklahoma most of the properties have been producing from 10 to 25 years. In this area, the commonest cause of loss or waste of oil on the leaseholds was found to be due to faulty pumping equipment and worn out and leaking storage and flow tanks. On one inspection trip through this area 58 lease storage tanks were repaired and 29 new tanks were installed at the request of the Survey engineer to replace old tanks that were leaking to such an extent that it was not safe to repair them. The repair and replacement work resulted in the elimination of all avoidable waste of oil from this source and the saving of several thousands od dollars to the lessee and the restricted Indian royalty holders.

In another Oklahoma case involving Indian lands the supervisor's office cooperated with the lessees in devising a method of treating cut-oil and high-tank bottoms. On one restricted Indian lease a combination of heat and chemical treatment resulted in the elimination of approximately 50 percent of the loss due to excessive accumulation of base sediment or high-tank bottoms. By the combination treatment of the bottoms, a large part of the base sediment is reconditioned and pumped back into the storage tanks as marketable oil.

The cases described above are cited to show that every effort is made to prevent waste of oil on lands under the supervisory jurisdiction of the Geological Survey.

4. *Elimination and prevention of fire hazards.*—Under the regulations, adequate and properly located burn pits are required for the removal and disposition of base sediment in a safe manner and to eliminate the fire hazard which would otherwise be present. Precautions are required to prevent blowouts of wells and oil-field fires of all types. Frequently, lease inspections have resulted in many replacements of leaky tanks, the repair or replacement of faulty lease equipment, and the removal of vegetation, all of which, prior to their correction, constituted oil-field fire hazards.

An inspection trip by a Geological Survey engineer may be cited as an example of efforts being made to eliminate and prevent fire hazards. The inspection revealed that a large number of tank batteries were unsafe and constituted fire hazards due to an accumulation of oil and base sediment around the tank bases. On this trip alone, 20 of such cases were cleaned up and the fire hazards removed. On another recent inspection trip by a district engineer it was noted that several wells had an accumulation of waste oil in their cellars. These were cleaned up on request and the sources of oil loss at the surface and fire hazard—leaky stuffing boxes, etc.—were repaired.

5. *Prevention of damage by water to strata capable of producing crude oil or natural gas, or both.*—The operating regulations of the Geological Survey in their application require the casing-off of open hole where porous or thief formations are present, thus excluding upper water from oil and gas-bearing formations, require the extension of casing through gas caps and gas-bearing formations in order to permit the production of oil with reasonable gas-oil ratios, and require the plugging of open hole below production that might develop bottom water. These requirements all contribute definitely to the elimination of physical waste by preventing damage to formations capable to producing oil or gas, or both, and by preventing the dissipation of reservoir energy.

An example of the many cases of well repairs involving the prevention of damage to oil and gas strata by intermediate water which have been made possible through the advisory, cooperative, and regulatory efforts of the Geological Survey is contained in a report of the following incident: A well was completed in the lower portion of a productive sand zone and obtained an initial production of 150 barrels of oil per day. Several months later, the casing was perforated in order to test an intermediate sand. Water entered the hole immediately and the total fluid pumped each day gradually increased in volume until 700 barrels of fluid were being produced, more than 90 percent of which was water. The formation was cavernous and several methods and materials were used unsuccessfully to shut off the fluid. Early abandonment of the well was in prospect. At the suggestion of the Geological Survey, gel-cement was pumped into the formation and a complete seal against the intermediate sand was obtained. The well was then cleaned out to bottom and produced 95 barrels of oil and 30 barrels of water daily. It is estimated conservatively that this well, about to be abandoned as noncommercial, will produce 175,000 barrels of oil during the next 10-year period, the approximate economic life of the well under present market conditions, as a result of cooperation between the Geological Survey and the lessee. It is also estimated that the net return in dollars to the lessee at the end of 10 years will have been $50,000.

6. *Prevention of the escape of crude oil from productive formations through drainage, seepage, or uncontrolled migration.*—Under the authority of the operating regulations the oil and gas supervisors and their representatives are constantly on the watch to prevent or control conditions which, if not corrected or checked, would permit the escape of crude oil from productive formations through drainage, seepage, or uncontrolled migration.

The oil and gas supervisors are authorized, as to lands under their jurisdiction and supervision, to fix the percentage of any oil or gas well that may be utilized when, in their opinion. such action is necessary to protect the productive formation, and to specify the time and method for determining the potential capacity of such wells. The lessee is required, pursuant to the regulations, to shut off and exclude all water from any oil- or gas-bearing stratum to the satisfaction of the supervisor and to determine the effectiveness of such operations must make a casing and water shut-off test before suspending drilling operations or drilling into the oil or gas sand and completing the well. The lessee is also required to test for commercial productivity all formations that give evidence of carrying oil or gas, the test to be made in a manner approved in advance by the supervisor.

As an example of the steps taken on Government land to prevent the escape of crude oil through drainage, seepage, or uncontrolled migration, there may be cited the case of an operator in California who proposed to complete certain wells on Government land without the segregation of two dissimilar productive zones. This practice is known to be conducive to waste by the loss of products from one zone to the other and the difficulties resulting from the nonsimultaneous encroachment of edgewater in the zones. The operator's proposal was, therefore, denied.

7. *Prevention of the premature release of natural gas from solution in crude oil.*—The regulations require the lessee to prevent the waste or wasteful utilization of gas and to pay the lessor the full value of all gas wasted by blowing, release, escape, or otherwise, at a price not less than 5 cents for each 1,000

cubic feet, unless such waste of gas under the particular circumstances involved is determined by the Secretary of the Interior to be sanctioned by the laws of the United States and of the State in which it occurs. As a general principle, gas produced should be beneficially used or returned to the sand from which it came. It is a requirement of the regulations that the production of oil and gas be restricted to such amount as can be put to beneficial use with adequate realization of values, and in order to avoid excessive production of either oil or gas, such production, when required by the Secretary of the Department having jurisdiction over the leasehold, is limited by the market demand for gas or by the market demand for oil.

A California field may be cited as an example of a case in which Survey engineers succeeded in preventing the premature release of natural gas from solution in crude oil. It was found by a study of the production records that the gas dissolved in the relatively heavy oil produced from this field was an important factor in producing the oil. Production statistics and curves presented to the operators convinced them that maintenance of back pressure to hold the gas in solution was essential to the economic life of the wells and the proper recovery of oil from the productive zones. The result of this conservation action is reflected in increased and more efficient recovery of oil from this field.

8. *Inefficient, excessive, or improper use of reservoir energy with particular reference to the operation of wells producing crude oil with inefficient or excessive gas/oil ratios.*—The conservation of gas, its effect on immediate and ultimate production, its value as a propulsive agent in the production of oil, both theoretical and practical, the manner of obtaining the most economical use of that propulsive force, and other related factors, have been discussed in technical petroleum literature for many years.

The primary purpose of conserving gas, other than for its fuel value, is to secure maximum economic oil production at a minimum total cost. Admittedly, in any field taken as a whole, oil can be recovered more cheaply if the propulsive energy of the gas is conserved than if such gas is dissipated needlessly and without regard to its capacity for useful work. It has been proved that after maximum recovery is obtained by wasteful and unrestricted flowing methods, large quantities of oil remain in the sand, some of which can be recovered by the application of expensive secondary recovery methods, but most of which will, perhaps, be forever lost to beneficial use insofar as present known practicable methods of recovery are concerned. No artificial means of oil production known to technicians today can drive oil to the well so completely and so economically as the gas within the oil in its original state.

The Geological Survey has long realized that the conservation and efficient utilization of gas are of paramount importance in the conservation and economical production of oil. The gas present or dissolved in a crude oil makes the oil more fluid and more capable of movement through the pore spaces of the reservoir formation to the well. The propulsive energy stored in the gas is the principal force conducive to such movement. The more gas present, the easier the oil moves, and the greater the force available to move it. The energy and solution values of oil field gas are of primary importance and should be given the utmost consideration in long-range recovery planning.

Many methods in present day use are of value in conserving gas and utilizing it efficiently. The effectiveness of the different methods will vary for different fields and for different wells, depending upon many underground factors seldom, if ever, constant for any given locality. It is recognized that no single method or group of methods can be universally applied, but that each well should be studied as an individual problem and the best method indicated by such study applied.

The Geological Survey is ever active to detect and, through remedial engineering practices, prevent the loss of gas and oil resulting from improper practices and outmoded production methods which may from time to time be practiced on the public mineral lands. The engineering principles applied, the helpful suggestions offered, the improved production methods initiated, and the remedial measures required where wasteful production practices, hazardous methods, and obsolete operating procedures are evident, generally result in increased revenues to the operators, to the lessees, and to the Government, through conservation of reservoir energy. The savings effected when wasteful practices are eliminated, when the gas-oil ratio of an oil well is reduced, or when gas previously wasted is put to beneficial use or conserved, through restrictive regulation, in its natural reservoir for future use, are definitely real but difficult to determine in actual monetary value. On the other hand, newly developed production from an old, depleted well and stimulated recovery through improved lifting methods are more tangible and are more easily evaluated, some of the factors involved being time, lifting costs, selling price, and the normal expected production decline for the area involved.

The following examples of the beneficial results obtained by the application of engineering principles to the production problems of the area supervised by one of the suboffices will be indicative of the results being obtained by all of the suboffices.

In a New Mexico field, required repairs to one well which was producing an excessive amount of gas resulted in reducing the gas-oil ratio from 5,000 cubic feet to 1,300 cubic feet of gas per barrel of oil, thereby effecting a monthly saving of gas under the prorated allowable estimated at 12,000,000 cubic feet. It is conservatively estimated that the saving in gas for the ensuing 12 months had a gross production value of more than $6,000.

At the request of the district engineer, three wells were successfully repaired in another field. The casing of a well used for lease development purposes was perforated opposite a zone which had been located as probably productive at the time the well was first drilled, and the formation acidized through the perforation, with the result that the production of gas was increased from 2,000,000 cubic feet daily to 7,600,000 cubic feet daily. The value of the increased gas developed as the result of applying acid stimulus to a lime zone is estimated as having amounted to $50,000 for the ensuing year. Another well in the same field, which had an excessively high gas-oil ratio, responded favorably to the required installation of a packer on tubing at a predetermined position in the pay zone. The gas-oil ratio of 16,000 cubic feet of gas per barrel of oil was reduced to 3,000 cubic feet per barrel of oil. At the prorated allowable production rate of the well, the gas saved by this one operation is estimated to have a fuel value of $23,750 a year, without consideration being given to the reservoir energy conserved. Required tubing and packer installation on a third well in the field was successful in reducing the gas-oil ratio from 26,000 cubic feet to 996 cubic feet per barrel of oil, with the fuel value of gas saved during the ensuing year estimated at $60,000.

In another New Mexico field a well was completed with an excessively high gas-oil ratio. Unsuccessful efforts were made by the operator to reduce the gas production. Consequently, the district engineer required restriction of production to the gas which could be marketed and the oil acccompanying it. The restricted flow of the well has resulted in a saving of gas valued at $100,000 for the ensuing year. In the same area study was made of the history and drilling records of other wells on the public-land leases and as a result appropriate repairs were made on five wells, involving four separate leases. In each case, the gas-oil ratio was successfully reduced and the savings in gas obtained for the ensuing year are estimated to have a value of about $128,000.

Required repairs, suggested mechanical changes, suggested perforation jobs, acid treatment under the engineer's approval, and experimental placement of packers and the installation of flow valves on tubing in another area of New Mexico definitely resulted in increased production and elimination of waste, with encouraging indications that the ultimate recovery of oil and gas will be increased over present estimates. The savings resulting from the reduction of gas-oil ratios and the value of increased production obtained by suggested and required repairs on eight wells involving six leases in the area were estimated to have a gross production value of $211,000 for the ensuing year.

10. *Plugging and abandonment of wells for the protection of reservoir energy and for the prevention of waste by or loss of subsurface waters.*—The operating regulations provide that the lessee shall plug and abandon promptly or condition as a water well any well on the leased land that is not used or is not useful for the purposes of the lease. Before abandoning a well, however, the lessee must submit to the supervisor or his representative a statement of reasons for abandonment and his detailed plans for carrying on the necessary work, together with duplicate copies of the well log if it has not already been submitted. The regulations further provide that a well may be abandoned only after receipt of written approval by the supervisor or his representative, in which the manner and method of abandonment shall be approved or prescribed. The regulations do not permit any productive well to be abandoned until its lack of capacity for further profitable production of oil or gas has been demonstrated to the satisfaction of the supervisor.

The Geological Survey's requirements for plugging and abandoning wells have served to protect oil and gas zones which, if not of use or economically producible at the present time, may be produced and utilized in the future as the technique in oil and gas recovery methods improves. The requirements for the proper plugging and abandonment of wells also serve to prevent the dissipation of reservoir energy, the harmful infiltration to formations of subsurface waters which might endanger future recovery, and the wasteful dissipation of such subsurface waters to the surface. Particular effort is made to see that abandoned wells are plugged in a manner to prevent migration of oil from one formation to another, or from seeping to the surface, and after such wells have been plugged and abandoned they are inspected from time to time to see that no drainage or seepage condition exists. In many instances, where permittees and lessees have defaulted under the terms of their undertakings with the Government, wells have been plugged and abandoned under contract at Government expense, under the supervision of the Geological Survey, suit being brought later, in a majority of these cases, against the surety and the permittee or lessee to recover the cost of the plugging and abandonment operations. Most of the plugging and abandonment work performed at the Government's initial expense has been done through the use of funds allotted to the Geological Survey by the Public Works Administration, only a very small amount of money having been appropriated directly by the Congress for this work.

11. *Prevention of miscellaneous wasteful practices.*—Upon the completion of a gasoline plant in a field in California, and the commencement of operations in said plant, it was learned by the Geological Survey that the gasoline recovered was less than that which should be expected from charcoal tests made of the gas. The method of testing used by the processor of the wet gasoline was considered very unsatisfactory and considerable pressure was brought to bear on the producer of the gas to establish a satisfactory testing procedure by which the volumes of recoverable hydrocarbons in the gas could be correctly estimated. Both the producer and the processor attempted to justify the method of testing and extraction then in use as being not only satisfactory to them but also efficient. The Survey, however, continued to urge the producer and processor to make changes in the absorption and distillation equipment in order to bring the plant up to an efficient basis. After these suggestions were finally adopted it was found that the plant efficiency increased 14 percent, making possible a conservation of approximately 9,000 gallons of gasoline per day. It is estimated that the savings resulting from the investigation of plant efficiencies, despite protests both from the processor and producer, amounted approximately to 3,000,000 gallons of gasoline during the last year of improved operations which, at 5 cents a gallon, would have a value of $150,000.

One of the problems confronting Federal oil and gas supervision involves cases where small leases not connected with the wet gas gathering line of a gasoline plant have relatively small wet gas production which is being wasted because it is not commercially feasible to treat for gasoline extraction. In one case in California the lease was producing approximately 100,000 cubic feet of wet gas daily, using only a portion for fuel and wasting the remainder. A small recovery of gasoline was made during the winter months through vertical drips installed on the derrick legs. Neither of two gasoline-extraction companies operating in the general area had collecting lines near this property. As a consequence, the lessee made no attempt to treat the gas properly and conserve the entire gasoline content. The Geological Survey had tested the gas on the leasehold in question on a number of occasions to determine volume and gasoline content and had made preliminary plans for the installation of an inexpensive gathering system. It also investigated the feasibility of small portable gasoline plants. In this case it was suggested to the owner of a used portable plant that it would be a profitable investment to install the plant on the leasehold property. The owner of the portable plant adopted the suggestion and arrangements were made to install the plant near the boilerhouse on the leasehold. The plant was soon manufacturing approximately 10,000 gallons of gasoline monthly besides returning to the lease sufficient dry gas to serve its fuel requirements without the necessity of the lessee purchasing additional fuel, as had previously been necessary. There was a gross saving of $700 a month in value of gasoline for the 2 years the portable plant was in operation, or a total of approximately $15,000. Of this amount the lessee received 40 percent, or $6,000, as its share.

The extent to which results in preventing avoidable waste are affected by private operations on contiguous non-Federal leases varies widely between districts and in different localities. In general, the cooperative spirit shown by operators on contiguous private leases in preventing avoidable waste on private lands has been reasonably good. In many cases where the operators of Federal leases are also the operators of contiguous non-Federal leases, no distinction is made by the operator as to operating practices on the non-Federal leases, and in such cases the operating practices are the same for both types of leases. In numerous cases, however, the operating regulations are accepted for non-Federal leases only when it is clearly to the advantage of the operator to do so. The chief difficulty is experienced with the so-called "shoestring" operator, who lacks experience and understanding of oil-field problems.

In cases where there is effective control of fields by virtue of unitized operations or because the Federal Government owns a majority of the land, excellent progress has been made in preventing avoidable waste. However, even in areas where the Federal Government has majority control because of its landownership there are certain wasteful practices which cannot be corrected through enforcement of the operating regulations in the absence of an effectively drawn and effectively enforced general conservation statute. Where the Federally owned lands are in the minority in any given field little can be done toward preventing avoidable waste on adjoining non-Federal acreages, unless there is an effective State conservation law which is being adequately enforced.

The amount of cooperation between the oil and gas supervisors and State conservation and regulatory bodies has, generally speaking, been satisfactory, but not wholly effective. Some States have excellent conservation laws but insufficient personnel with which to enforce them. Other States have no conservation laws but have adopted almost in whole the act of February 25, 1920 (41 Stat. 437), and the oil and gas operating regulations of the Federal Government to govern the method of leasing and operating State-owned lands. Other States have adopted the Federal oil and gas operating regulations to govern operations on both State and patented lands.

### Prevention of Avoidable Waste at Osage Reservation, Oklahoma

All expenses of administering the affairs of the Osage Tribe of Indians in Oklahoma, including the supervision of oil and gas production on the reservation, have been paid from tribal funds. The supervision of its leases, therefore, has not been transferred to the Geological Survey as has the supervision of mining activities on other Indian reservations.

Several oil pools have been discovered on the Osage Reservation, from which there has been very large production both of oil and gas. Total oil production has been more than one-half billion barrels. There has been production on the reservation for more than 35 years, and in the early days there undoubtedly was much waste as operations were conducted there in much the same manner as in other fields without much attention being paid to true conservation. This has been changed and, under the present regulations of the Interior Department governing leases on the Osage Reservation, it is not considered that there is any waste as defined by section 5 (b) (1) of H. R. 7372, Seventy-sixth Congress, first session.

All oil and gas deposits underlying the Osage Indian Reservation are reserved to the tribe until April 8, 1983. Therefore, the entire royalty interest is in the tribe and all leases are subject to the same control. This is very different from the situation on many other reservations, where it has often been necessary to permit the lessee to conduct wasteful practices similar to those on adjoining non-Indian lands in order to prevent drainage.

There is no problem of waste before recovery in the oil fields on the Osage Reservation. There is no substantial loss of oil through evaporation. The reservation is largely equipped with gas-tight field tanks, and tank bottoms are treated for final and complete recovery. No gas is burned in flambeau lights or permitted to blow into the air. There is a natural-gas reservoir where summer gas can be stored and taken out as a winter-load use. All available residue gas is pumped back into the formation from which it came under pressures varying from a few pounds to 800 pounds per square inch, except in cases where the oil and gas inspector consents that a lesser amount be returned.

The oil and gas inspector has the power to give all notices and orders needed to prevent waste. He may order discontinued any operations which he considers wasteful. Where the gas-oil ratio is too high, production is curtailed and in some instances wells are completely shut down. Wells are not permitted to flow at a rate which will result in their premature abandonment. The use of vacuum to increase production is prohibited where it is not considered a proper method of production.

All lands on the reservations are leased in 160-acre tracts and well locations are subject to approval by the oil and gas inspector. Uniform drilling programs, therefore, have been carried out.

In the older fields only stripper wells remain, and many of these have been plugged and abandoned. At present the stripper wells provide about two-thirds of the production on the reservation. In the newer pools, principally the Naval Reserve pool and the south Burbank pool, production is prorated and steps are being taken to preserve the reservoir energy. The South Burbank pool is considered a good example of what can be done to preserve reservoir energy. The area of the pool is 4,157 acres. An agreement for unit operation affecting 2,277 acres has been approved. One lessee is designated to operate the unit, all major questions being referred to an advisory governing board comprising representatives of each partner. In addition to the proration of production mentioned above, 71.7 percent of the available residue gas is being injected into the producing horizon. There are 171 producing wells, of which 128 are flowing, and most of them will continue to flow for several years if the gas-pressure maintenance program is continued. The average per-acre recovery to date in this field is 5,621 barrels. It has been estimated that in the old Burbank field the wells had quit flowing when the average per-acre recovery was 4,000 barrels.

A similar pressure-maintenance program in the Naval Reserve pool, beginning 2 years ago, has stopped the decline in oil production. Before the repressuring started, walls were ceasing to flow. Since the gas injection has been carried on, few wells have come on the pump and some have been taken off. Of the 249 producing wells in this field, 69 are now flowing. There are 21 input wells in this field now in operation. The investment is more than offset by the reduction in lifting cost.

Repressuring is being practiced on other fields in the reservation to the extent that gas is available, and in some instances gas is being purchased off the reservation for this purpose. The repressuring is accomplished as efficiently as possible. Input wells are carefully selected and are especially prepared, cemented, and packed.

Under an amendment to the regulations made effective March 26, 1938, the oil and gas inspector is authorized to designate any field or pool for cooperative unit development or operation for the purpose of utilizing all residue gas for injection into the field from which it came for increasing the recovery of oil from the field. Less than the full volume of residue gas so available may be injected into the sand only with the consent of the oil and gas inspector. As gas is the main expelling medium on the Osage Reservation, this amendment, together with the existing regulations, gives the oil and gas inspector authority to take any action necessary to prevent as fully as may be done under known methods the dissipation of reservoir energy.

The present practices on the Osage Reservation are believed to be carried on in a manner as free from waste as can be obtained under present methods of oil recovery. It is felt that this reservation, particularly the newer pools, offers a good example of what can be done in the way of conservation in oil development under proper regulation. Undoubtedly new methods will be perfected in the future in connection with the advancement of the oil industry which may make some of the present methods obsolete, but because of the unit royalty interest on the Osage Reservation and the fact that all lessees are under the same regulations and can be required to take the same conservation measures, the Osage oil fields will be in a favorable position to take advantage of any new developments.

Mr. Cole. We will recess until 2 o'clock.

(Thereupon a recess was taken until 2 p. m.)

## AFTER RECESS

The subcommittee reassembled, pursuant to the taking of recess, at 12:30 p. m.

Mr. Cole. The committee will come to order.

We will be very glad to hear at this time Rear Admiral H. A. Stuart, Director of Naval Petroleum Reserves, United States Navy Department.

## STATEMENT OF REAR ADMIRAL H. A. STUART, DIRECTOR OF NAVAL PETROLEUM RESERVES, UNITED STATES NAVY DEPARTMENT

Mr. Cole. Admiral Stuart, for the purpose of the record I would like to get your full name and your experience with the subject and association with it, and any other preliminary or introductory statement you care to make. Such prepared statement as you have pertaining to the Naval Petroleum Reserve and the Navy's position with respect to the oil industry, and any other statements pertaining to this investigation and the legislation proposed will be gladly received.

Admiral Stuart. I am Rear Admiral H. A. Stuart, United States Navy, Director of Naval Petroleum Reserves.

I have been connected with oil questions off and on for something like 20 years, and for the last 6 years I have been Director of Naval Petroleum Reserves.

I would like to read the following statement:

The importance of petroleum and its products as necessities of modern warfare can no longer be denied and those departments of the Government charged with the defense of the United States must be assured of ample supplies of these vital materials if they are to be able at all times to carry out their missions. To this end the Navy Department is of the opinion that the petroleum resources of the United States must be conserved and the naval petroleum and other naval fuel reserves protected, as far as it is possible to do so, from depletion by operations conducted on both fee-owned and leased lands within and without the reserves.

While many petroleum technologists and economists assure us that the petroleum resources of the United States are ample, that there is no occasion for their conservation and that there is no prospect of a shortage in the near future, it is my opinion that these so-called vast reserves of petroleum are largely dependent on much higher prices because of the greater development and production costs necessary to reduce the oil to possession. Due to the constantly increasing world demand for oil (over 2,000,000,000 barrels in 1937) the day when oil can be obtained in abundance, quickly and cheaply from relatively shallow wells is rapidly drawing to a close, at least as far as the resources of the United States are concerned.

Less than a decade ago few oil wells were producing from a greater depth than 5,000 feet and seldom were "wildcat" or prospect wells drilled more than two or three thousand feet before the "wildcatter" abandoned his well and moved on to explore elsewhere when he failed to find production. Today many wells are producing from depths between eight and ten thousand feet and one prospect well has been drilled to a depth of over fifteen thousand feet. The present indications are that prospecting for oil will, in the not distant future, even exceed that depth. It is not uncommon today for prospect wells, favorably located, to be carried to depths of oven ten thousand feet at costs of hundreds of thousands of dollars as compared with the tens of thousands formerly felt to be justified in such work. These facts cannot be disputed and can only be explained by the acknowledgment on the part of the oil industry generally, that the regions where oil might be discovered at relatively shallow depths and at small expense have nearly all been explored.

Naval Petroleum Reserve No. 1, in California, constitutes what is probably one of the few remaining large areas in the United States where, from comparatively shallow wells, it can be reasonably anticipated that, within a relatively short period of time, intensive drilling will develop a daily production of oil sufficient to meet a sudden national crisis. It is not improbable that some day the safety of the United States may depend on the oil remaining in this reserve and therefore it must be protected from further depletion and the Government's lands therein must be consolidated so that the largest possible area will be embraced in a single tract of land.

With a large increase in the tonnage of the Navy, larger air forces in both the Army and Navy, and the tendency for complete mechanization of various Army units to increase their mobility and effectiveness, the necessity for the Government to possess adequate petroleum reserves in the ground becomes a constantly more important factor in the missions of the country's armed forces to provide properly for the defense of the Nation and its outlying possessions.

The success of military operations at home and of naval operations at sea are becoming more and more dependent on having available for all requirements ample supplies of the best possible fuels—all of which are dependent on access to large reserves of petroleum. In war time the facility and speed with which both the Army and Navy can maneuver will unquestionably determine the effectiveness of military and naval operations and will be dependent on an abundance of proper fuels for all purposes during the entire period of action. Any country attempting an aggressive war or fighting defensively, which has limited petroleum resources, against a foe having access to practically unlimited supplies of oil will be, even though it may possess some superiority in armaments, in the long run up against a disadvantage almost impossible to overcome.

Foreseeing the necessity of having at all times an assured oil supply for all naval purposes far in the future, the Navy and Interior Departments took action as early as 1908 to provide it from the potential oil lands of the public domain. The Interior Department's work of examining and classifying public lands was thereafter carried on with a view to locating and setting aside a tract or tracts of potential oil lands believed to contain petroleum sufficient to meet the Navy's estimated reserve requirements of 500,000,000 barrels of recoverable oil.

On the recommendation of the Director of the United States Geological Survey, two tracts of land in Kern County, Calif., were set aside by Executive orders of President Taft for the exclusive use or benefit of the United States Navy. Two additional reserves were later set aside by Presidents Wilson (Teapot Dome) and Harding (Alaska) in 1915 and 1923, respectively.

There are now four naval petroleum reserves: Numbers 1 and 2 in California, known as Elk Hills and Buena Vista Hills reserves, respectively; number 3 in Wyoming, known as Teapot Dome reserve; and number 4 in Alaska. Of these reserves, number 1, Elk Hills, has by far the greatest value and is the Navy's principal underground oil reserve. Practically all of Naval Reserve No. 2 has been leased, due to the checker-boarded positions of the Government's lands among developed fee-owned tracts in the reserve. Reserve No. 3, Teapot Dome, which was returned to the Government upon the termination of the receivership January 7, 1928, has a much smaller oil and gas content than Reserve No. 1. The value of Naval Petroleum Reserve No. 4 in Alaska is not known as yet. This reserve is handicapped by its remote location well within the Arctic Circle.

Mr. COLE. No. 3 is not shown on this map, of course?

Admiral STUART. No, sir; that is just Nos. 1 and 2.

Naval Petroleum Reserve No. 1, created by Executive order of September 2, 1912, comprises 38,073 acres on the west side of the San Joaquin Valley in the Elk Hills district of the Sunset-Midway field. This reserve lies about 30 miles southwest of Bakersfield and about 125 miles northwest of Los Angeles, Calif. Production is obtained from sands occurring at depths of 3,000 feet or more in a zone several hundred feet thick. This reserve has an extreme length measured east and west of 13 miles and a maximum width of 9 miles measured north and south. Of the total acreage in the reserve the Government owns 32,195 acres, 4,662 acres are owned by the Standard Oil Co. of California, and 1,216 acres are involved in litigation to quiet titles thereto. The United States is a party to these actions, claiming that the lands were known to be mineral lands when surveyed, and therefore titles thereto were never vested in the State of California through which claimants hold. Of the land owned by the United States, 31,766 acres are unleased and comprise the area of the Pan American Petroleum Co. leases which were canceled by the Supreme Court decision of February 28, 1927, and by the United States Court of Appeals decision of February 5, 1932. Of the Government-leased land comprising 429 acres, the Belridge Oil Co. has a lease of 142 acres; and the Pan American Petroleum Co.—now Richfield Oil Corporation—has three leases covering the remaining 287 acres. The only production at present from Government lands in reserve No. 1 is from the Pan American—Richfield—and Belridge strip leases.

The President's Naval Oil Reserve Commission, appointed by the President on March 25, 1924, to make a special study of the naval-petroleum-reserve situation, in a report made to him on January 22, 1927, stated that the future value of Naval Petroleum Reserve No. 1 is "even more than was originally believed, and that this value can be conserved until most needed." The Commission also stated that the "original policy of using this Elk Hills reserve as a form of national insurance can now be put into full force and effective action taken in protection of the Navy's future efficiency." The geologists' figures indicate that the original recoverable content of petroleum from Government land in the reserve was estimated at approximately 600,000,000 barrels, of which amount the production to June 30, 1939, has been 51,305,581 barrels, approximately 8.55 percent.

The permanent integrity of reserve No. 1 depends entirely upon the extent to which production can be controlled and prevented on the private acreage inside the reserve and on the private and public land acreage immediately adjacent to the reserve.

Naval Petroleum Reserve No. 2, created by Executive order of December 13, 1912, comprises 30,181 acres in the Buena Vista Hills district of the Sunset-Midway oil field, on the west side of the San Joaquin Valley, in Kern County, Calif., and is adjacent to and immediately south of Naval Petroleum Reserve No. 1. It has an extreme length east and west of 13 miles, and an extreme width north and south of 8 miles. Of the total acreage, 19,735 acres are privately owned and

10,446 acres are owned by the United States. Of the private acreage, the Standard Oil Co. of California owns 16,515 acres, or about three-quarters. Of the Government land, practically all, or 9,226 acres, have been leased. About 15,000 acres, or one-half of the total area of reserve No. 2, is proved oil land, of which more than three-quarters has been developed.

The original recoverable content of oil from the Government's leased lands in this reserve is estimated to have been 150,000,000 barrels; production to June 30, 1939, has aggregated 107,127,426 barrels, approximately 71.41 percent. The privately owned or patented lands so thoroughly checker-board Naval Reserve No. 2 that its value as a future reserve from present sands is practically nothing. However, in this reserve there is an excellent possibility of obtaining deep production from sands below the present oil-bearing horizons, and these sands, it is believed, constitute a potential reserve which the Navy considers well worth every effort to conserve. Therefore, reserve No. 2 still has a high potential value for exchange purposes if it could be used in perfecting and preserving Naval Petroleum Reserve No. 1, as a source of income to the Treasury which partially, at least, defrays current appropriations for fuel for the Navy and as a potential oil reserve of considerable magnitude in its deep sands.

Naval Petroleum Reserve No. 3, created by Executive order of April 30, 1915, comprises 9,321 acres in Natrona County, Wyo., about 35 miles northeast of Casper, in the central part of the State. Production is found at depths of 2,400 feet or more. All of the Government land was included in the lease made to the Mammoth Oil Co. April 7, 1922, which was voided by the decision of the United States Supreme Court on October 10, 1927 (275 U. S. 13), and returned to the United States by court order upon the termination of the receivership January 7, 1928. Sixty-five oil wells and twelve gas wells were drilled by the Mammoth Oil Co. The gas wells were shut in by the receivers in accordance with an order of the court. The oil wells were all shut in by the receivers on December 31, 1927, and the Navy Department expects to keep them shut in.

The total production from Teapot Dome to date has been 3,550,228 barrels, of which approximately 1,442,496 barrels were produced by the Mammoth Oil Co. prior to the establishment of the receivership in March 1924. It is estimated that the recoverable oil content of reserve No. 3 amounts to about 20,000,000 barrels.

Although Teapot Dome is located far inland, it is valuable as an underground reservoir of a good quality oil for use in times of future national emergency.

Naval Petroleum Reserve No. 4, created by Executive order of February 27, 1923, is estimated to comprise 35,000 square miles in extreme northwest Alaska. The area involved is known to contain seepages and other indications of petroleum. The lands included in this reserve were "reserved for 6 years for classification, examination, and preparation of plans for development, and until otherwise ordered by the Congress or the President." The reserve has been examined in a general way by the field parties of the United States Geological Survey, a portion of the expense of the examination having been defrayed by the Navy Department.

Reserve No. 4 lies well within the Arctic Circle, nearly 1,000 miles from the nearest open port and remote from the railroad. Transportation to the United States would have to be by water, or through British Columbia, if by land. The coast is without harbors, is open to navigation by light-draft vessels intermittently over a period of not more than 2 months of the year. The mean average temperature is about 10 degrees Fahrenheit, and it is believed that the ground is permanently frozen to a depth of some 600 feet. No development work has been undertaken. During each of the fiscal years 1923 and 1924 the United States Geological Survey had a party in the field during the summer, funds for the work being supplied by transfer from the Navy Department's appropriations.

The value of this reserve is unknown at the present time. The results of the Interior Department's survey work in connection with this reserve are fully reported in United States Geological Survey Bulletin 815.

There are two naval oil-shale reserves in Colorado, Nos. 1 and 3, and one oil shale reserve in Utah, No. 2. These reserves were created to provide for the time when the supply of oil from wells become inadequate to meet the demand for petroleum products. The Navy Department has made a study of the oil-shale situation with the object in view of making use of this product as a wartime reserve at such times as the shale industry may become established on a practicable commercial basis.

Naval Oil Shale Reserve No. 1, created by Executive order of December 6, 1916, comprises 41,353 acres in Garfield County, Colo., situated on the north side of the Colorado River Valley, between Rifle and Grand Valleys, at a minimum distance of 3 miles from the river and the main line of the Denver & Rio Grande Western Railroad. The shale strata, which are about 1,000 feet thick, lie horizontal and are exposed along the southern and eastern boundaries of the reserve in the upper part of steep-faced cliffs 2,000 to 3,000 feet high.

Naval Oil Shale Reserve No. 3, created by Executive order of September 27, 1924, comprises 22,600 acres of land bordering reserve No. 1 on the east, south, and west; while less than 15 percent of reserve No. 3 is shale land, its acquirement was necessary to afford working space for any retorting and refining plants, for the disposal of spent shale, and for other operations connected with mining, retorting, and refining the shale and its products.

Naval Oil Shale Reserve No. 2, created by Executive order of December 6, 1916, comprised originally 86,584 acres of land in Uintah and Carbon Counties, Utah, in the Book Cliffs Plateau, near the head of Desolation Canyon on Green River, about 45 miles east-northeast of Price on the main line of the Denver & Rio Grande Western Railroad. Four thousand eight hundred and eighty acres were added by Executive order of November 17, 1924, consisting of lands within the reserve which had not been included in the first withdrawal. The present area of Naval Oil Shale Reserve No. 2 is 91,464 acres. The shale strata are similar to those in Naval Oil Shale Reserve No. 1, and are exposed in the high bluffs along Green River in the Western part of the reserve and in the bluffs along Hill Creek in the eastern part.

The process of retorting oil from shale is still in an experimental state. However, for the purpose of encouraging the formulation of plans for making this source of oil available for use on a commercial basis, the Navy Department cooperated with the Bureau of Mines in securing appropriations from the Congress so that the Bureau of Mines could carry on certain experimental tests in connection with the development of a practical and economical method of extracting oil from shale. With these funds the Bureau of Mines constructed on Naval Oil Shale Reserve No. 3, near Rulison, Colo., two experimental oil-shale plants. The results of the Bureau of Mines' experiments are reported in United States Bureau of Mines Bulletin 315.

Upon assuming office on March 24, 1924, the Secretary of the Navy, the Honorable Curtis D. Wilbur, took personal charge of naval-petroleum-reserve matters; since that date, all activities in connection with the naval petroleum and oil-shale reserves, and matters of general policy relating to the future fuel supply of the Navy, have been under the immediate supervision of the Secretary.

On May 3, 1924, the Office of the Inspector of Naval Petroleum Reserves in California was established, with headquarters in Los Angeles, Calif. At the same time there was also established the Office of the Inspector of Naval Petroleum and Oil Shale Reserves, Wyoming, Colorado, and Utah, with headquarters at Casper, Wyo.

On October 15, 1927, the Navy Oil Office, under the Director of Naval Petroleum and Oil Shale Reserves, was established as a division of the Secretary's office in the Navy Department.

Mr. Cole. Admiral, may I interrupt you just a moment? Back two paragraphs, where you referred to the Bureau of Mines Bulletin 315, does that bulletin reflect not only the Bureau of Mines but the Navy Department's experimental work as to the use of shale as a source of oil?

Admiral Stuart. Yes, sir.

Mr. Cole. And you adopt that as about the very last word on the subject?

Admiral Stuart. Well, that was several years ago. I don't know that there is a last word, but it was; at the time it was; yes, sir. It is still generally in an experimental stage, and will be until it gets into quantity production. And there is very little activity, practically none, going on in the country at the present time.

Mr. Cole. How about other countries?

Admiral Stuart. There is very little there. There may be a little in Scotland and some in Europe, but there is practically none anywhere.

On March 17, 1927, the President, by Executive Order No. 4614, issued as a result of the decision of the Supreme Court, February 28, 1927, in the first *Pan American case*, revoked Executive Order No. 3474 of May 31, 1921, which had committed to the Secretary of the Interior the administration and conservation of the naval petroleum reserves. The Executive order of March 17, 1927, was mutually construed by the two departments affected as vesting in the Navy Department the administration of all leases in the naval petroleum reserves heretofore issued pursuant to authority of the President, in accordance with the act of February 25, 1920 (41 Stat. 437), as well as of all leases issued under the provisions of the act of June 4, 1920 (41 Stat. 812). The Department of the Interior retained and exercised administrative control only over such leases as had been issued pursuant to authority imposed directly upon the Secretary of the Interior by the Mineral

Leasing Act of February 25, 1920, such control being exercised with the cooperative approval of the Navy Department. In the opinion of the two departments, good administration required that control of all leases in the naval petroleum reserves should be vested in one department. Accordingly the Secretary of the Interior, after consultation with the Secretary of the Navy, submitted to the Congress a bill proposing that jurisdiction over all oil and gas leases issued by the Secretary of the Interior on lands in naval petroleum reserves be transferred to the Secretary of the Navy. This bill was enacted into law and approved by the President on February 25, 1928 (45 Stat. 148). Subsequent to the Executive order of March 17, 1927, the Secretary of the Navy and the Secretary of the Interior, in order to give full effect to the provisions in the act of June 4, 1920, applying to the naval petroleum reserves, worked out an agreement interpreting the matter of administration of and jurisdiction over lands and leases in the naval petroleum reserves. It was desirable that there should be no duplication of work or organization. The administrative agreement was put into effect on August 1, 1927, was revised February 1, 1934, and has since been followed.

By its terms the Interior Department has placed at the disposal of the Navy Department the technical staffs and field forces of the Geological Survey for the performance of all work in connection with gaging oil, gas, and gasoline produced from leases in the naval petroleum reserves, calculating the royalties due the Government, and acting in an advisory capacity to the naval inspectors in the field. The Navy Department reimburses the United States Geological Survey for the cost of the services thus rendered by an annual transfer of funds.

The cost of administering the naval petroleum reserves is defrayed by an annual appropriation entitled "Operation and conservation of naval petroleum reserves." Expenditures made on behalf of the naval petroleum reserves have averaged about $78,000 per fiscal year. This yearly cost of administration and maintenance is to be contrasted with revenues to the Government from oil and gas royalties which have aggregated about $35,354,466 since July 1, 1920. Due to the curtailment of oil production and to low prices, revenues from royalties from naval petroleum reserve leases have fallen for the past few years; and the sum of $947,268, accrued during the fiscal year 1939, represents operations conducted at about 70 percent of their potential.

Mr. Cole. Admiral, does the $78,000 figure of average expenditure for the fiscal year take into consideration the cost of the properties?

Admiral Stuart. No, sir.

Mr. Cole. Or what they were purchased for?

Admiral Stuart. Well, there wasn't any cost to them; they were lands set aside as public lands.

Mr. Cole. All of them have been set aside?

Admiral Stuart. Yes, sir. There have been none of them purchased.

Although both naval petroleum reserve No. 1 and No. 2 were checkerboarded with railroad lands and school sections, geologists of the United States Geological Survey believed them to be the best lands available for the proposed naval reserves and the only known areas believed to contain sufficient oil for the Navy's purpose.

It was also believed that many of the selections of the railroad had been made with the knowledge on the part of the company that the lands were mineral and therefore could not legally be acquired for the reason that the lands were not of the character contemplated to pass under the Railroad Land Grant Act.

Since no mineral discoveries had been made on the public lands set aside in naval petroleum reserve No. 1 prior to its reservation, it was believed that none of the claimants holding under mineral filings had acquired any interest in their claims which would entitle them to patents under the mining laws. While discovery of oil had been made in the Buena Vista Hills (naval petroleum reserve No. 2) on Government lands prior to the setting aside of the reserve and certain areas had already been patented under the laws for acquiring mineral lands, extensive development had not begun until after the reserve was established and claimants to the Government lands there were for the most part operating on claims based on filings purported to have been made prior to the reservation and the good standing of which was, to say the least, open to question.

Following the establishment of the naval petroleum reserves in California, the Navy sought to quiet title to such lands as it acquired and through the facilities of the General Land Office and the Department of Justice to determine what areas within the reserves came under the jurisdiction and control of the Navy and what areas were properly in the possession of others. For more than 25 years the Navy Department has pressed its claims in the courts in an effort to protect the interests of the Government in the naval petroleum reserves, and the end is not yet in sight.

It is not proposed to discuss the various legal battles the Navy has fought in defense of its naval petroleum reserves. It will suffice to point out, however, that at no time during any of this litigation has the Navy coveted any man's property, nor does it do so now. At all times the Navy has always adhered to its policy that it acquired certain rights by virtue of the Executive orders establishing the naval petroleum reserves and that any controversies over these rights should be decided by the courts. The Navy has insisted on getting, for the benefit of national defense, all it is entitled to—no more.

The most important case involving lands in the naval petroleum reserves now before the courts is the section 36 case, in which the Secretary of the Interior in a decision rendered on January 24, 1935, determined that title to section 36, township 30 south, range 23 east, Mount Diablo meridian, a section of land in naval petroleum reserve No 1, has remained in the United States and has never been vested in the State of California or its transferees.

Mr. Cole. That is the little green patch of land shown in the center of the pink area?

Admiral Stuart. Yes, sir; right in the center.

In this action special assistants to the Attorney General were appointed by the President to prepare the Government's case to dispossess the claimants to section 36 and to recover the value of the oil and gas produced from the section during the period it has been in their possession. On November 8, 1937, Judge Yankwich, of the United States district court, heard the case in equity at Fresno, Calif., and on December 4, 1937, handed down an opinion awarding the Government $6,164,102.42 damages without interest prior to the date of the judgment, in addition to the above sum the company was required to expend approximately $50,000 to recondition the wells drilled on section 36 to stand idle indefinitely without wasting oil or gas. On March 10, 1938, the defendants filed an appeal from the decree of the district court. The Government's special counsel also appealed from that part of the lower court's opinion which denied the Government interest on the value of oil and gas produced from the month in which the products were reduced to possession by the company. The case was argued before the United States court of appeals in San Francisco, Calif., on February 24, 1939, before Judges Denman, Mathews, and Healy, presiding.

On September 28, 1939, about 6 months later, the United States Circuit Court of Appeals for the Ninth Circuit vacated the order submitting the section 36 case to it, and ordered a rehearing for the reason that Judge Denman had disqualified himself and Judges Mathews and Healy were in disagreement. At the rehearing Judge Garrecht was ordered to sit with Judges Mathews and Healy, and this rehearing was held on October 27, 1939, in San Francisco, and of course we have heard nothing yet, as the result of that hearing.

As far back as 1914, Mr. J. H. G. Wolf, then a consulting engineer in the employ of the Navy and Justice Departments pointed out the advisability of both the Navy and Southern Pacific Railroad consolidating their holdings in the naval petroleum reserves by exchanging lands so that the possession of each would be in solid blocks and the checkerboarded condition which scattered the holding of both parties eliminated.

Due to the involved litigation which followed the Navy's efforts to establish its title to the reserved lands, it was not until June 30, 1938, that legislation was finally passed authorizing the Secretary of the Navy to take necessary action with a view to improving the Navy's position so as to enable it better to protect and conserve its oil lands particularly in naval petroleum reserve No. 1. This legislation among other things—

1. Authorizes the Secretary of the Navy, with the approval of the President: (*a*) To contract with owners and lessees of land within or adjoining the naval petroleum reserves in order to consolidate and protect the oil lands owned by the Government for the purpose of conserving oil and gas in the ground; (*b*) to exchange Government land in naval petroleum reserve numbered 1 for privately-owned land or leases in naval petroleum reserve No. 1, in order to consolidate both Government and private lands into solid blocks, or, failing this (*c*) to acquire the privately-owned lands within naval petroleum reserve No. 1 by purchase or condemnation; (*d*) to use any moneys due the United States from royalties from any of its naval petroleum reserves or in compensation for the wrongful production of oil and gas from lands within naval petroleum reserve No. 1 in connection with (*b*) and (*c*) above.

Mr. COLE. Admiral, has the Navy Department exercised its right to acquire by purchase or condemnation any lands as authorized by this Act?

Admiral STUART. I did not understand your question.

Mr. COLE. Reading at the top of page 17, subsection (c) says the Secretary of the Navy is authorized in the act to acquire the privately owned lands within naval petroleum reserve No. 1 by purchase or condemnation. Have you acquired any land under that authority?

Admiral STUART. Not yet, sir. We are making a study of the problem and trying to find out the values of the land, both the Government and the fee land. We first have to try to make an exchange with them, and then if we cannot make an exchange we are authorized to go ahead and purchase or condemn. It is just in the process of development now, and we are trying to find out "where we are at."

Mr. COLE. Upon what basis would you condemn? What would be your authority to condemn?

Admiral STUART. If we cannot come to an agreement with them and we cannot get a fair price, just condemn it, because we need it.

Mr. COLE. On the theory that the Federal Government has a right to condemn private property possessing oil because of the need for what purpose?

Admiral STUART. National defense.

Mr. COLE. For national defense?

Admiral STUART. Yes, sir.

Mr. COLE. All right.

Admiral STUART. 2. Provides for the termination of all leases in naval petroleum reserves, not incorporated in and extended by a unit or cooperative plan of operation and development involving adjoining private lands, at the end of their initial 20-year periods.

3. Authorizes the appropriation of such sums as may be necessary to carry out the provisions of the act.

It is hoped that this legislation will enable the Government to solve its problem in naval petroleum reserve No. 1 and enable it to conserve there indefinitely whatever oil the lands contain.

With the prospect of a material increase in the tonnage of the United States Navy during the next few years, the Navy Department has surveyed its present petroleum reserves with a view to determining their adequacy with respect to the Navy's probable future fuel oil requirements. This survey has disclosed that the petroleum content of the lands comprising the naval petroleum reserves is far from sufficient for the Navy's future needs. For this reason the Navy has been extremely anxious to add to its present petroleum reserves any other proved or potential oil lands which might be found suitable for oil reserves.

Mr. COLE. Admiral, speaking of the Navy's future needs, which are quite important at this time, to what extent, if you know, do the needs of the Navy for petroleum increase in time of war? Can you give us a figure, a percentage figure?

Admiral STUART. Well, I would say probably it increases five or six times; maybe more than that.

Mr. COLE. Five or six times?

Admiral STUART. Yes, sir.

Mr. COLE. And that would be what percentage of our total production?

Admiral STUART. Well, at the present time we use around 9,000,000 barrels of fuel oil. This represents, at present rate of refinery practice, the use of 36,000,000 barrels of crude oil. It might increase to as much as 50 million barrels of fuel oil, or an equivalent quantity of 200,000,000 barrels of crude oil of the average grade refined in the United States.

Mr. COLE. That is, in time of actual war?

Admiral STUART. Yes, sir.

Mr. COLE. And it increases, I presume, in a time of emergency such as we are in now?

Admiral STUART. Of course, it does increase materially.

Mr. COLE. Your statement that the Navy's petroleum reserves are far from sufficient for the Navy's future needs, that is based, I assume, on the assumption that you would not have to rely on acquiring it from other sources, from private sources?

Admiral STUART. Yes, sir; we cannot depend on it, absolutely.

Mr. COLE. Have you any observation you want to give to the committee as to what the Navy might need? You said the Navy reserves are not sufficient to meet the needs of the Navy in case of emergency?

Admiral STUART. Well, that is undoubtedly true. Private industry would supply a great deal, but the point is that they are decreasing the original content all the time; it certainly is not being formed anything like as rapidly as it is being taken out. It is rather the future than the present in which we are interested. You see, as a Nation we produce over 60 percent of the oil that is produced.

Mr. COLE. All right, sir; you may proceed.

Admiral STUART. Although both the Navy Department and the Department of Justice received numerous letters from individuals seeking to persuade the Government to take some action to prevent private interests from producing oil from submerged lands along our coasts, nothing was done in this matter other than to refer the correspondence to the Office of the Judge Advocate General—the legal section of the Department—to determine what interests, if any, the United States might have in such oil production.

No cases were discovered wherein the courts had ever passed upon the question of ownership or title to minerals in the submerged lands below low tide and within the 3-mile limit of the United States or any of its possessions. The Interior Department had declared that the statutes relating to public lands did not give that Department authority to issue mineral leases or permits below the line of high tide—that the submerged land strip, although it might be found mineral bearing, could not be construed as being public lands within the meaning of the statutes relating thereto and governing their disposal.

Senator Gerald Nye of North Dakota introduced a bill in the Seventy-fifth Congress, which after amendment, had the purpose of preventing the further depletion of the submerged lands of oil and setting aside such petroleum deposits as were known or might hereafter be discovered therein as additional reserves for the Navy. When called upon for a report on the bill, the Judge Advocate General's office gave as its opinion that the Government unquestionably had superior rights to such minerals as might be found in the submerged lands but in the absence of any statute relating thereto or a declaration by Congress citing the Government's interests therein, the United States could not well interfere in a matter over which the States had assumed jurisdiction.

Believing that the submerged lands off the California coast in the Pacific and off the coasts of Texas and Louisiana in the Gulf of Mexico probably would be found to contain oil deposits in addition to those already known, the Navy Department has given its full support to all proposed legislation which would enable it to secure such oil deposits as additional naval reserves but has strongly insisted that in such legislation all legal rights of others in such lands should be protected and that the controversial question as to whether minerals in submerged lands along our coasts are rightly the property of the Federal Government or the adjacent State should be determined by the courts.

Mr. COLE. Is that question being litigated now, Admiral?

Admiral STUART. No, sir. We had hearings on these bills last spring, but there was never a report on it from the committees.

Mr. COLE. That bill gave the Federal Government the right to litigate the question?

Admiral STUART. Yes, sir.

Mr. COLE. And does not attempt to confer any rights on the Federal Government, that is through Congress, except what the courts might decide?

Admiral STUART. That is right.

Mr. COLE. Is that the purpose of the legislation?

Admiral STUART. Yes, sir.

Mr. COLE. What is the present status of that legislation?

Admiral STUART. It is still in committee; neither the House Judiciary Committee nor the Senate Public Lands Committe have reported out the bill or have rendered any report on the hearings.

Mr. COLE. The bill which the Navy Department advocates?

Admiral STUART. Yes, sir; the Navy Department and also the Department of Justice and the Department of the Interior.

The American Petroleum Institute estimated the known petroleum reserves of the United States at 17.348,000,000 barrels as of January 1, 1939, or approximately 14 years' supply at the 1938 rate of production, 1.277,000,000 barrels. This amount of oil then represents the Nation's present backlog, a quantity which tends to be augmented in years when discoveries exceed production and decrease when new discoveries fall below production.

Mr. COLE. Admiral, does your Department rely exclusively on the statements of the American Petroleum Institute as to the status of the petroleum reserves?

Admiral STUART. To a large extent; yes, sir. We also consider the Bureau of Mines figures and the Department of the Interior figures. American Petroleum Institute figures are inclined to lean to the optimistic side.

Mr. COLE. You have not any independent figures?

Admiral STUART. No, sir; we have no independent figures. We have to take their estimates.

Mr. COLE. There has been some statement made during the hearings this week that the figure of 17,348 million barrels which you quote here as of January 1, 1939, should be at the present time, because of discoveries during the year 1939, closer to 22 million instead of 17 million?

Admiral STUART. Well, this is the statement as of the 1st of January 1939.

Mr. COLE. You have not any information in your Department to support any figure other than this?

Admiral STUART. No, sir.

Mr. COLE. All right; proceed.

Admiral STUART. This backlog or producible reserve of oil has gradually accumulated over the past life of the industry as a result of many discoveries each year of relatively shallow (500 to 5,000 feet) producing areas capable of producing at a slowly diminishing rate over a relatively long period of time. Of late years, however, new discoveries of this type have fallen far below the annual rate of consumption of petroleum and our reserves have been maintained and augmented by discoveries of deep-seated (5,000 to 15,000 feet) oil horizons, many of which have been found within or adjacent to the known shallower fields. What the life of production from these deep sands will be is not yet known but it would seem to be beyond question that production from them will be progressively shorter lived with increasing depth. In my opinion, such deep production will add materially to the oil reserves of the United States but will not add at all to the life of the industry, as it is probable that all deep wells will have ceased production due to higher operating costs before some of the shallower wells now producing have yielded the last of their recoverable oil.

In the 20-year period since 1918, world production of petroleum has increased from 503,515,000 barrels in 1918 to 1,992,488,000 barrels in 1938, or approximately 300 percent, while production in the United States has increased in the same period from 355,928,000 barrels to 1,213,254,000 barrels, or 243 percent. The United States produced 70 percent of world production in 1918 but only 60.8 percent in 1938, a fact which would seem to indicate that the United States is slowly falling behind in its position and is therefore using up its oil reserves at a faster rate than other world reserves are diminishing.

In 1918 the domestic demand for petroleum amounted to 387,780,000 barrels of the 503,515,000 barrels of world production, or 77 percent; in 1938 it amounted to 1,178,399,000 barrels of 1,992,488,000 barrels of world production, or a little less than 60 percent. In 1918 imports of petroleum exceeded exports by 31,852,000 barrels, but in 1938 exports of crude oil exceeded imports by 50,861,000 barrels, seeming to indicate that the world demand for petroleum outside the United States is just in its infancy and will probably increase much faster in the future than will domestic demand. It would seem therefore logical to expect exports of crude to continue to increase at the expense of domestic reserves—an unhealthy condition from the viewpoint of national defense.

Mr. Cole. Would that be a good point, Admiral, to comment on the Venezuelan treaty of yesterday? That is, it changes the figures here, of course?

Admiral Stuart. Yes, sir; but we would have to see what the figures are to know what difference it would make. I don't know just what difference that quarter of a cent per gallon is going to make.

Mr. Cole. Would you care to look at this release from the Department of State and see what the differences are in there? I would be interested to know what changes if any it would make in your figures.

Admiral Stuart. At present it is half a cent a gallon, and this changes it, as I understand from the newspapers, to a quarter of a cent a gallon.

Mr. Cole. I think somewhere in that statement the State Department, in explaining the significance of the quota arrangement, pointed out that the total quantity of crude oil processed in 1938 was 1,165,015,000 barrels. Five percent of this is 58,251,000 barrels. The average imports of taxable crude petroleum for the last 5 years were 34,539,000 barrels.

And your figures, I think, are 30, are they not, in the last year?

Admiral STUART. 26.5 million. The 1938 exports of crude oil exceeded the imports. It is the difference between the two—77,254,000 less 26,412,000—that was 50,842,000 barrels.

Mr. COLE. Well, those figures I just read were released from the State Department in that connection.

Admiral STUART. Was that the difference? What were the exports?

Mr. COLE. This just deals with the imports. The average imports of taxable crude petroleum for the last 5 years were 34,539,000 barrels. And 5-percent increase, as this contemplates, would be 58,251,000 barrels. Your statement you have just given to the committee does not take into consideration the estimate of the Department of State in view of this new agreement?

Admiral STUART. No, sir.

Mr. COLE. I am wondering, in that connection, if you want to insert anything at this point or at any other place in your prepared statement?

Admiral STUART. I would rather look it over and give you a statement later, perhaps.

Mr. COLE. All right, sir.

Admiral STUART. A study of the tariff concessions on crude petroleum, topped crude, and fuel oil, made in the trade agreement signed at Caracas, Venezuela, November 6, 1939, leads me to the conclusion that the agreement will probably result in somewhat greater imports of heavy asphalt base oil by refineries on the east coast where asphalt and fuel oil for bunkers are in large demand. I do not think the agreement will seriously interfere with the coastwise movement of the higher gravity mixed base oil from the Gulf coast inasmuch as these oils will still be necessary to supply the gasoline requirements of eastern United States and probably for exports to Europe. However, it is probable that shipments of asphalt base oils from California to the east coast may wholly or partially be displaced by similar oils from South America.

Of the 50,861,000 barrels of crude oil exported in excess of imports 26,459,000 barrels, more than 50 percent, were exported from the Pacific coast and represented production from the California fields. It has also been reported that stocks of California crude oil were increased some 6,741,000 barrels during 1938—which oil, together with the more than 26 million barrels exported, amounted to 13.3 percent of California's 1938 production, 249,749,000 barrels. It would then seem that California's production last year could well have been decreased at least one-eighth to the advantage of both the State's petroleum industry and its reserves.

During 1938 the United States produced approximately 60.8 percent of world oil production and 13.25 percent of the remaining 39 percent was produced in Mexico and South America, areas which in time of war would be dominated by a strong United States Navy.

At the present time the United States, Canada, and Mexico produce approximately 63.23 percent, South America 13.25 percent, Europe 13.68, and Asia and the East Indies 9.84 percent of world production.

The importance of California oil in a region barren of other cheap natural fuels in connection with the State's commerce and industry as well as its necessity for the needs of the Pacific Fleet cannot be too strongly stressed. It is therefore essential that this resource abundant though it may appear to be at present must be made to last as long as possible. The conservation of California's oil supplies is deemed by the Navy Department to be of paramount importance in connection with the defense of the country's western border, Alaska, and its Pacific Ocean possessions. The Navy must therefore continue to support all measures taken which have for their purpose the conservation of the State's oil and gas resources to the end that the life of the industry in the State wil be of maximum duration.

Mr. Cole. Admiral, do you know the results of the referendum yesterday in California?

Admiral Stuart. Well, the morning papers said it lost by about 2 to 1.

Mr. Cole. You mean the law was defeated?

Admiral Stuart. The law was defeated; yes, sir.

Mr. Cole. The decision in California yesterday was in direct conflict with the recommendation of the United States Navy?

Admiral Stuart. The Navy, the Secretary of the Interior, and the President.

Mr. Cole. Well, I might add my name to that group, also.

Admiral Stuart. Assuming that the naval petroleum reserves do contain large quantities of oil and gas which can be conserved until needed, we must also assume that this oil when ultimately produced will be efficiently utilized and that all of the more valuable fractions will be extracted by refining before the residue is available for fuel for ships. Even though no larger percentages of the lighter products are removed, and in all probability this will not be true, than the oil now yields, it is believed that these reserves actually represent a backlog of oil amounting to less than 20 years' peacetime supply for our future Navy. This is not believed to be an adequate fuel reserve and it must be added to it, if it is at all possible to do so.

Should it be possible to reserve also for the Navy whatever oil may be present in the submerged lands it is hoped that such a reserve would add another 10 years' peacetime supply and make the naval petroleum reserves represent a possible 30 years' peacetime supply for the Navy, a period estimated to cover the useful life of all ships now built or building. For this reason the Navy Department has supported and will continue to support all efforts to conserve for the Navy the probable oil lands forming extensions under the sea of known oil fields and those probable oil-bearing lands which are entirely in the submerged lands along our coasts.

Mr. Cole. Admiral, do you want this plat to accompany your statement in the record? I don't know how we could unless you would supply some identification of the color, how it would be very useful. I would like to have it in there.

Admiral Stuart. What is that, sir?

Mr. Cole. The plat here, I wondered if you wanted that as a part of your statement in the record?

Admiral Stuart. If you would like.

Mr. Cole. Being in color, and identified by color, it does not show up in our printed records.

Admiral STUART. I think we can fix that up so that it can be identified, sir. We will fix that up so that it can be identified.

Mr. COLE. All right.

(The plat referred to faces this page.)

Mr. COLE. Mr. Wolverton wants to ask you some questions, Admiral.

Mr. WOLVERTON. Does the Navy Department through the Government own or hold by lease any lands in other countries with oil resources?

Admiral STUART. No, sir.

Mr. WOLVERTON. Does the Navy Department through the Government sell to other countries or to private industry any of the oil that is now a part of its reserves?

Admiral STUART. These offset wells in No. 1 and these leases in reserve No. 2 furnish a certain royalty, and we sell the royalty to the company that produces the oil and they dispose of it where they please.

Mr. WOLVERTON. Well, is that land that is owned by the United States?

Admiral STUART. Yes, sir.

Mr. WOLVERTON. Or is it a joint ownership with private industry?

Admiral STUART. No, sir; that is land owned by the United States.

Mr. WOLVERTON. In view of your statement that there is hardly sufficient for the future needs of the Navy, on what theory does the Government sell to private industry?

Admiral STUART. If we did not lease this land, all the oil would be drained out by the adjoining owner. We only lease it to keep them from getting it. If we could, we would close it all down, just as we did in Wyoming in Teapot Dome.

Mr. WOLVERTON. What percentage of the oil produced from Navy land is used for Navy purposes, and what percentage for private sale?

Admiral STUART. It is all disposed of by private sale. We just let the lessee take the oil in kind, and he pays us the market price for it.

Mr. WOLVERTON. What proportion of the total production from Navy ground is sold to private industry?

Admiral STUART. Well, the royalty in reserve No. 2, I think, is nearly 14 percent.

Mr. WOLVERTON. Does the Navy purchase any oil for the use of the Navy from private industry?

Admiral STUART. Yes, sir; it is all purchased from private industry.

Mr. WOLVERTON. I understood you to say that the needs of the Navy at the present time were about 9 million barrels per year?

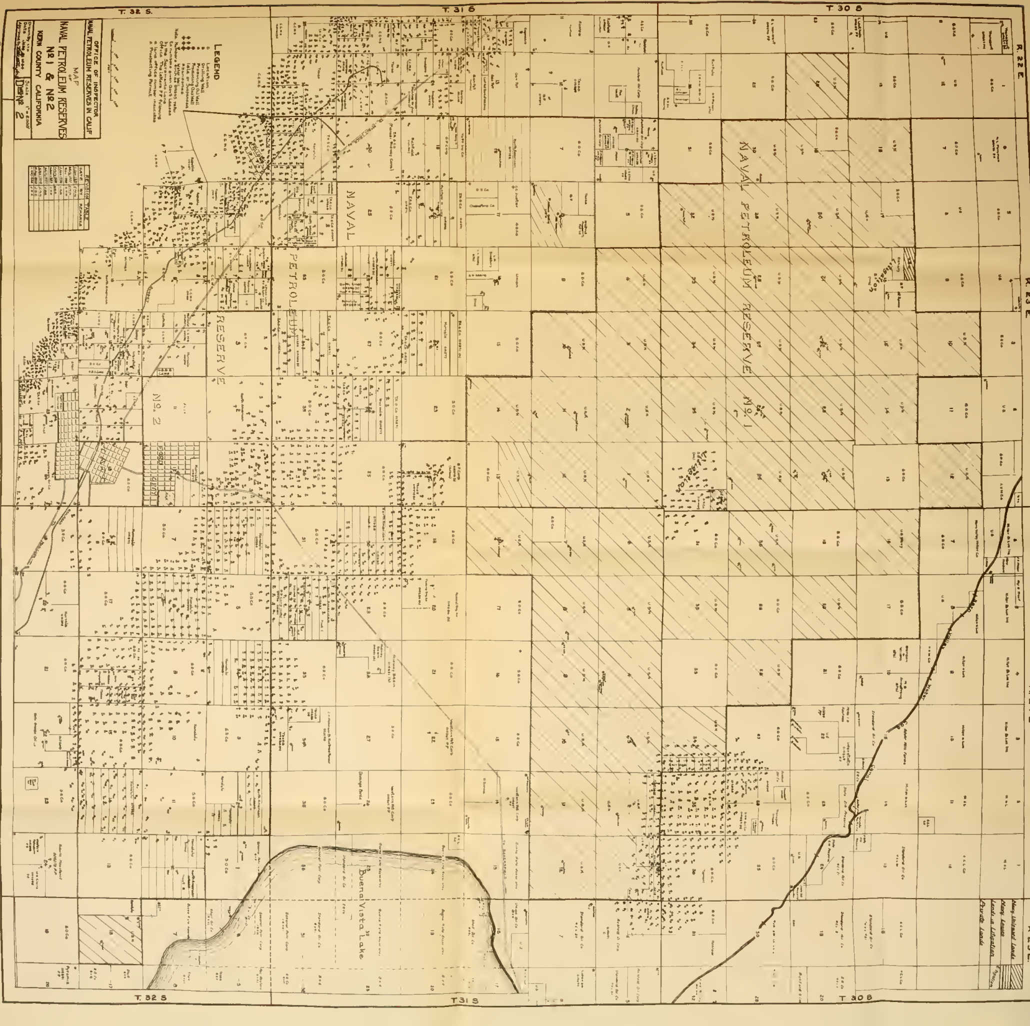
Admiral STUART. It is roughly that; yes, sir.

Mr. WOLVERTON. How much do they purchase, and how much is produced from their own land?

Admiral STUART. It is all purchased, as fuel oil and gasoline and Diesel oil.

Mr. WOLVERTON. Then we are not using the reserves that belong to the Government for present purposes?

Admiral STUART. No, sir. It is as broad as it is long; that money goes into the Treasury as "miscellaneous receipts," and we find that it is just as simple to make the purchase as it is to take that oil and trade it for fuel oil. We would not get any better bargain.



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Mr. WOLVERTON. Well, I am not speaking of it from that standpoint; I am speaking of it from the standpoint of conservation. If the present resources are inadequate, in your opinion, it would seem to me to justify the present policy of the Department purchasing elsewhere.

Admiral STUART. Yes. We only produce oil that is absolutely necessary to keep the adjoining owner from getting it. If it were possible, we would close them all down and not produce any at all. But it is just to keep the adjoining landowner from draining it all away that we allow production at all.

Mr. WOLVERTON. You spoke of our resources being inadequate for future needs. Just what does your reference to future needs contemplate?

Admiral STUART. The increase of the Navy and increased use of oil and its products—fuel oil, gasoline, and Diesel oil.

Mr. WOLVERTON. Are you able to estimate what that would be for the immediate future?

Admiral STUART. No, sir; because it depends upon the conditions under which you could operate. With war, it would be entirely different, and if you increase the Navy it is going to be entirely different.

Mr. WOLVERTON. In view of the importance of our oil reserves for national defense, has the Navy Department expressed any opinion with respect to whether there should be a derease of oil exported or an increase of oil imported?

Admiral STUART. No, sir; the Navy Department I don't think has. I have my own views about it.

Mr. WOLVERTON. Well, in view of the emphasis that you have placed upon the necessity of conserving our oil reserves, would it not seem an important matter to have some opinion from the Navy as to whether there should be a decrease of exportations or an increase of importations, as a means of conserving our present oil resources?

Admiral STUART. I think so; yes, sir.

Mr. WOLVERTON. You do not care to express your own personal opinion with respect to it?

Admiral STUART. Yes; I can express my own personal opinion, for what it is worth.

Mr. WOLVERTON. I will be very glad to have it.

Admiral STUART. I would like to see the imports increased and I would like to see all the exports stopped. But I don't think you can do it.

Mr. WOLVERTON. Well, the view that you have expressed would seem to be consistent with the emphasis you place on the necessity of conserving our oil resources.

Admiral STUART. Yes, sir.

Mr. WOLVERTON. Do you contemplate that the present war conditions will materially change any of the statements that you have made in your prepared statement given to the committee today?

Admiral STUART. That is pretty hard to say. It depends on how the present situation develops.

Mr. WOLVERTON. Is there any present indication that because of the war needs abroad there will be greater demand from foreign sources for American oil?

Admiral STUART. I don't know that there is at present, but as a guess I would say it probably will if they once get to fighting over there in Europe.

Mr. WOLVERTON. Would you care to express an opinion as to whether you think there should be an embargo on oil?

Admiral STUART. No, sir; I don't think I had better express an opinion on that.

Mr. WOLVERTON. I am fearful that the use of the word "embargo" by me may have made you fearful?

Admiral STUART. It did; yes, sir. [Laughter.]

Mr. WOLVERTON. Have you in your Department any basis for expressing any opinion to the committee at this time as to the percentage of increase that there will be in the use of oil by foreign nations at war?

Admiral STUART. No, sir; because it depends on conditions.

Mr. WOLVERTON. I don't suppose the war has gone long enough to give definite information?

Admiral STUART. I have none, sir.

Mr. WOLVERTON. In view of the war situation abroad, with the possibility of increased use of oil, has the Department considered expressing any opinion to Congress or to this committee with respect to further conservation of oil for our own use? In other words, is the possibility of foreign use likely to increase to a point where it might be necessary for some policy to be adopted to conserve our own oil?

Admiral STUART. I cannot answer that question.

Mr. WOLVERTON. With reference to the legislation that the Department approves, as to the ownership of lands under water within the 3-mile limit, does that legislation contemplate only those areas in which oil is probably located, such as California, Texas, and Louisiana, which is specifically referred to in your statement, or is it of a general character, applying to all lands bordering our sea coast?

Admiral STUART. It does not apply to all lands; only where oil is probable. In fact, the present bill, the so-called Hobbs bill, H. R. 176, applies only to California. That is the one that we really had hearings on last spring.

Mr. WOLVERTON. Is the Navy Department making any effort to obtain additional lands known to contain oil, or is it satisfied to hold merely what it has at the present time?

Admiral STUART. Submerged land areas, that is the only one I know of.

Mr. WOLVERTON. I mean, aside from submerged lands?

Admiral STUART. No, sir.

Mr. WOLVERTON. Does it conduct any series of surveys to ascertain the existence of oil in other Government-owned lands?

Admiral STUART. No, sir; I know of none in other places where we could have a reserve.

Mr. WOLVERTON. I think from your statement that you looked with some degree of concern upon the large proportion of the California product used in foreign trade?

Admiral STUART. Yes, sir.

Mr. WOLVERTON. Due to the fact that it would be the most available area to supply oil to our Pacific fleet in the event of emergency?

Admiral STUART. Yes. sir.

Mr. WOLVERTON. To what extent, if any, is our oil from the California field exported to Japan?

Admiral STUART. If I should give you that, it would be hearsay. It would be better if you got it from the Department of Commerce, I think.

Mr. COLE. I think that is possibly in some of the exhibits offered in the record yesterday.

Mr. WOLVERTON. That is all.

Mr. COLE. Admiral, just one other question. Commander A. B. Anderson, of the Navy, and Colonel Rutherford, of the Army, participated in the report on Energy and National Resources as presented by the National Resources Committee.

Commander Anderson, of the office of the Chief of Naval Operations, and Colonel Rutherford, Director of the Planning Branch of the Army, had about the same information as you had on this subject, all of which was made available to the National Resources Committee?

Admiral STUART. Yes, sir.

Mr. COLE. In the bill, which is before us for consideration, as well as the subjects covered in the resolution directing the investigation, is this statement, under the heading of Findings and Declaration of Policy, on page 2 [reading]:

> (2) It is hereby declared to be the policy of Congress, through the exercise in this Act of its power to provide for the maintenance of an adequate national defense and to regulate interstate commerce, to further the conservation of petroleum by the elimination of the wasteful methods and practices above referred to insofar as such methods and practices may be avoidable, and to encourage and assist the various States in their efforts to prevent the waste of petroleum.

Do you adopt that statement, Admiral Stuart, as a proper one for Congress to find and declare at this time, possessing the knowledge you do of our petroleum problem?

Admiral STUART. It depends on a great many things. If the States do not have adequate laws properly enforced, I think something of this sort is necessary.

But if you mean every word of this act, that is something else.

Mr. COLE. In your judgment is it proper for Congress to say at this time as a matter of policy that the maintenance of adequate national defense of the United States requires a further conservation of the petroleum by the elimination of wasteful methods and practices referred to insofar as such methods and practices may be available and also to encourage and aid the States in their effort to prevent the waste of petroleum. In other words, if Congress is to look to our national defense and our war power in approaching a problem of this kind, I think there must be some basis in fact for so doing, and one—certainly one of the most reliable, and one of the most dependable authorities on the subject—is the attitude of your office speaking for the Navy Department of this country.

Admiral STUART. I think we do need something of the sort; yes, sir; as a general policy; yes, sir.

There is one point, Mr. Chairman, in connection with section 8.

Mr. COLE. May I interrupt you, Admiral?

Admiral STUART. Yes, sir.

Mr. COLE. You were about to say something, Admiral.

Admiral STUART. I must state, of course, we have no clearance from the Budget; the Navy Department has no clearance from the Budget in regard to expressing an opinion on this bill, and we desired to have section 8 revised. We have come to an agreement with the Interior Department as to how that should be revised, in order to make sure that the naval petroleum reserves are adequately protected in connection with this bill.

Mr. COLE. I was just about to ask you about that section.

Admiral STUART. And we have agreed with certain officials in the Interior Department, and the Secretary of the Interior approved it, upon a change, and with that change effective we have no objection to the bill in general.

Mr. COLE. I think you can depend on this committee, Admiral, not to make any recommendations to take from your department control over deposits owned by the United States unless you are in the picture very definitely.

Admiral STUART. Thank you.

Mr. COLE. One other question, Admiral, and I think that is about all. On page 6 of your statement is this paragraph. I will read it:

> The permanent integrity of reserve no. 1 depends entirely upon the extent to which production can be controlled and prevented on the private acreage inside the reserve and on the private and public land acreage immediately adjacent to the reserve.

All of that, of course, is in the State of California.

Admiral STUART. All of what, Mr. Chairman?

Mr. COLE. All of the land to which you refer in that statement is in the State of California?

Admiral STUART. You mean as to location?

Mr. COLE. As to location.

Admiral STUART. Yes, sir; reserve No. 1 is in Kern County, Calif.

Mr. COLE. So that such control of private and public land acreage adjacent to reserve No. 1 is exclusively in the State of California, and you say that—

> The permanent integrity of reserve No. 1 depends entirely upon the extent to which production can be controlled and prevented on the private acreage inside the reserve and on the private and public land acreage immediately adjacent to the reserve.

Admiral STUART. Yes, sir. You see, the Standard of California owns practically all of those sections in the middle of the reserve. What we would like to do is to purchase it, but it costs money, and we first want to try to exchange with the Standard. If they will not agree to an exchange, then we should purchase. We have to obtain their acreage in order to protect it. If Congress gives us the money, the thing to do is to go out and purchase it; find the value of it and then purchase it. There is no question about it.

Mr. WOLVERTON. Has any estimate been made as to the cost?

Admiral STUART. Well, the estimates are very sketchy. We have made estimates, but we do not like to give them out.

Mr. WOLVERTON. What do you think would be the outside cost of the lands adjacent to the Navy lands, if you purchased them?

Admiral STUART. I would not like to say, sir, as long as we are trying to negotiate with the Standard Oil Co.

Mr. WOLVERTON. You are trying to negotiate?

Admiral STUART. Yes, sir.

Mr. Wolverton. Has any price been suggested by those with whom you are negotiating?

Admiral Stuart. No, sir.

Mr. Wolverton. Has any price been suggested by the Navy Department to them?

Admiral Stuart. No, sir. We are trying to conduct investigations now, trying to find out what the value is. You see there has not been a great deal of drilling, except on the edge of the reserve, and we have to take what information we have and from that make estimates.

Mr. Wolverton. We are speaking in terms of big sums these days for national defense, all of which I personally am in accord with. It would be interesting to know what could be properly spent to preserve our rights on these lands that now seem to be disturbed by adjoining owners.

Admiral Stuart. We would have to get some rather definite appraisals, even before we went to court about it. We would have to defend if we went into court in condemnation proceedings. We would not want to go off half cocked. We would like to make as close an estimate as possible before we did that.

Mr. Wolverton. Do you have the power of condemnation?

Admiral Stuart. Yes, sir; subject to the authority to make exchanges, acreage for acreage, or value for value.

Mr. Wolverton. If there is failure to agree upon exchange, can you then proceed by condemnation?

Admiral Stuart. Yes, sir.

Mr. Wolverton. It would seem that should be a very strong weapon in your hands for securing a proper price.

Admiral Stuart. I think so. That is why we had it put in there.

Mr. Wolverton. You have not used it yet?

Admiral Stuart. No, sir; we have not yet arrived at that stage of the proceedings.

Mr. Cole. But they might change their minds before going to the jury.

We thank you, Admiral, very much.

Admiral Stuart. Thank you, Mr. Chairman.

Mr. Cole. Colonel Rutherford.

## STATEMENT OF COL. HARRY K. RUTHERFORD, DIRECTOR OF THE PLANNING BRANCH, OFFICE OF THE ASSISTANT SECRETARY OF WAR

Mr. Cole. Colonel, will you state your full name and occupation for the record.

Colonel Rutherford. Yes, sir. Mr. Chairman, my official position is Director of the Planning Branch in the office of the Assistant Secretary of War, and my name is Col. Harry K. Rutherford. My particular activity in that capacity is the heading up for the War Department, under the Assistant Secretary, for all the War Department activities relating to industrial mobilization. In the Planning Branch we have to make continuing studies of the resources of the country applicable to the national defense and studies regarding the availability of all the supplies necessary for the maintenance of the armed forces of the War Department in the event of war and for the mobilization of those resources in the possibility of an emergency.

I have no prepared statement to offer to the committee today, Mr. Chairman, but I would like to make a few remarks that I think probably will be pertinent.

Mr. Cole. We will be very glad to hear from you, sir.

Colonel Rutherford. In our work in this industrial mobilization, we work very closely with the Navy and pool all our resources and all the information that we are able to collect from other sources and other authorities.

I believe Admiral Stuart has given you a great deal of the background which is applicable to the problem before the committee, and that of course the Army goes along with because we work with the Navy in collecting it.

I might say that we estimate that the Army's consumption of petroleum products would be roughly about 20 percent of that of the Navy. Therefore, our interest in petroleum products, while very important, is subordinated to that of the Navy. And we, therefore, are glad to go along with the Navy in working out the problem in which they have the predominant interest.

In computing our requirements in petroleum products in the event of a major war, which is, of course, our objective, much depends, of course, on the nature of the war and the locality where it will be fought and other problems of that sort. But the present and the increasing mechanization of the Army equipment leads us to believe that in the event of a major emergency the consumption of petroleum products caused by that war would probably be in the neighborhood of at least 15 percent above what is normally consumed in the country.

Now that is making no allowance for possible curtailment of less essential civilian needs which would be possible in an emergency. But in making our plans, we prefer not to require anything of that sort in the beginning, but rather to assume that the needs of the general population as well as the War Department will be met.

Mr. Wolverton. Colonel, when you said war was your objective, I assume you meant all of your planning contemplates war as a possibility?

Colonel Rutherford. Yes, sir. Being the head of the planning branch, all of our work there is, of course, planning something in the future; no particular enemy is visualized and the possible maximum effort a long time in the future, but something that nevertheless we must visualize as far as plans are concerned. But nothing in immediate prospect, of course.

Mr. Wolverton. The only reason I comment on it was you said war was your objective, and I knew you did not mean it in that particular way.

Colonel Rutherford. Well, I get the point. Quite right, sir.

In view of the increasing mechanization of Army equipment, therefore, the availability of petroleum and its products is just as important to the War Department as any of the other strategic materials that we have talked about in the past, and for which Congress was able to furnish us some money last year for collecting a stock pile. As we all know, the War and Navy Departments have been working together for many years to collect a stock pile of these strategic materials that are of primary importance for the purpose of assuring ourselves of an available supply in the event of an emergency. The conservation of supplies which are perhaps not inexhaustable is exactly along the same line, and the War Department is very much in favor of assuring ourselves of an indefinite supply of this very basic material.

I do not believe I have anything more to add, Mr. Chairman, unless someone would like to ask a question.

Mr. COLE. Colonel, in this bill before us, H. R. 7372, in section 2 which is entitled "Findings and Declaration of Policy," being of course the finding by Congress based upon the factual set-up which this committee might develop, and is this language:

> It is hereby declared to be the policy of Congress, through the exercise in this act of its power to provide for the maintenance of an adequate national defense and to regulate interstate commerce, to further the conservation of petroleum by the elimination of the wasteful methods and practices above referred to insofar as such methods and practices may be avoidable, and to encourage and assist the various States in their efforts to prevent the waste of petroleum.

Do you find any fault with that statement?

Colonel RUTHERFORD. No, sir; that sounds very constructive. I believe that any cooperative effort that could be carried out that will accomplish the purposes we all, and certainly in the War Department we feel is essential, would be well worth the effort. And if it is not possible of accomplishment in a cooperative way, I believe it is sufficiently important to require possibly some other action. But I certainly believe the War Department would be in favor of the general policy that has been mentioned.

Mr. WOLVERTON. What is the oil consumption of the Army at this time?

Colonel RUTHERFORD. I endeavored to find the latest figure before I came down, but it is procured by so many different agencies and in such different forms that it was impracticable to do so. My nearest estimate would be approximately one-fourth or one-fifth of what the Navy consumption is today, which is, as I got it from Admiral Stuart, some nine million barrels annually. The War Department consumption possibly would be one and a quarter million barrels; that is, of all kinds of oil products.

But that does not represent our maximum consumption, by any means, because we are becoming more mechanized every day and there is a very pronounced tendency to greater and greater consumption of petroleum products in the service.

Mr. WOLVERTON. Do you have any estimate of future needs based on whatever increase there may be in the mechanization?

Colonel RUTHERFORD. We have had to make estimates for wartime, for the preparation of our wartime plans. The maximum consumption that we visualize as a result of present conditions might be in the neighborhood of ten to twelve million barrels annually. Now, that is looking a long distance in the future, but we have to do that and, as I said before, it would be based a great deal on the character of the war, where it was being fought and the type of weapon that would be predominant in that particular situation, and so on.

Mr. WOLVERTON. Does the War Department have any representatives with the British and French Armies or the German Army, so they would be in position to have some first-hand information as to the oil requirements in time of war?

Colonel RUTHERFORD. Yes, sir; we have our regular military attachés in all of those countries. Just how much accurate information as to the consumption during a war period they would be able to obtain it is difficult to say. I could endeavor to find out for the committee, if you think it would be useful.

Mr. WOLVERTON. Well, I only had in mind whether you would be able to benefit by present war conditions in judging the war needs.

Colonel RUTHERFORD. We, of course, base our present figures on the consumption in peacetime. We know that these trucks and planes and tanks and whatnot would be engaged so much more in wartime and therefore we can arrive at a statement of approximate requirements.

I think the same problem comes up in regard to the consumption of artillery ammunition in the service and the using up of guns and all that sort of thing. It has to be taken on that basis and then multiplied by the number of hours a day you are going to use that weapon. And that is the way we arrive at our requirements.

Mr. WOLVERTON. I assume that a war at present or in the future would have greater demands than in the past war?

Colonel RUTHERFORD. Yes, sir: it is continually increasing.

Mr. WOLVERTON. Was there any difficulty in the past war to procure oil in the necessary quantity?

Colonel RUTHERFORD. No, sir. There was occasional difficulty in getting it to the front on account of lack of transportation, but I recall no serious difficulty with the actual supply itself, sir.

Mr. WOLVERTON. Did the American Army at that time draw only on our own oil resources or did they obtain oil through sources that were available to our Allies?

Colonel RUTHERFORD. I have no information on that, sir. I have the definite impression that we furnished the Allies a considerable portion of their requirements and that they in turn kept us supplied.

Mr. COLE. That is all, Colonel; thank you.

## STATEMENT OF RALPH J. WATKINS, NATIONAL RESOURCES COMMITTEE

Mr. COLE. Dr. Watkins, will you state your full name and your association with the subject of petroleum, your present position, and the name of the staff with you? The committee will be glad to receive any statement you care to make.

Mr. WATKINS. Mr. Chairman, my name is Ralph J. Watkins. My present position is economic adviser on the staff of the National Resources Planning Board. I am a native of Texas, and had my undergraduate training and part of my graduate training at the University of Texas. I later completed my graduate work at Columbia University. I have served on the faculties of the University of Texas, the Ohio State University, and the University of Pittsburgh. My training has been in the field of economics, and my experience has been that of a director of research.

Mr. COLE. Before you proceed, I want to state that President Roosevelt in his letter dated July 22, 1939, to the chairman of the Committee on Interstate and Foreign Commerce— and this letter is in the hearings—stated at the outset, in the first paragraph [reading]:

> On February 15, 1939, I transmitted to the Congress a report on energy resources by the National Resources Committee wherein certain recommendations were made relative to oil and gas problems in the United States.

That part of the letter which I quote deals with the work, as I understand, of which you were in charge?

Mr. Watkins. Yes. I was going to say, Mr. Chairman, that I directed for the National Resources Committee their study of energy resources which the President transmitted to Congress on February 15. It was ordered printed as House Document 160 and was officially released on August 28 under the title "Energy Resources and National Policy." My appearance here today, as well as that of my associates, is in response to your written request of October 24.

May I also say, Mr. Chairman, that this is a group presentation, and I would like to indicate the names of my associates who will take part in this presentation. Dr. Glenn E. McLaughlin is an economist and consultant to the National Resources Planning Board.

I, by the way, will give you a brief statement of the recommendations which were advanced in this report and some indication of the public interest in conservation of petroleum.

Dr. McLaughlin will talk on the economic aspects of waste and conservation in the oil and gas industry.

My second associate, Mr. Ben E. Lindsly, is senior petroleum engineer on the staff of the Securities and Exchange Commission, and will talk on unit operation of oil pools.

Mr. E. G. Dahlgren is associate valuation engineer, oil, on the staff of the S. E. C. He assisted Mr. Lindsly in the preparation of the statement on unit operation, which will be presented, however, by Mr. Lindsly.

Mr. Hale B. Soyster, already identified, is appearing here to take part in the discussion only; he does not have a formal presentation.

Mr. Cole. Sort of a round table?

Mr. Watkins. Yes; precisely. I might comment that this energy resources study was very much of a group undertaking. I believe we had 23 authors of that report.

Mr. Cole. Mr. Lindsly was with us in 1934, as well as Mr. Soyster.

Mr. Watkins. Yes; Mr. Lindsly, I believe, was joint author of the report with Mr. H. C. Miller in the 1934 investigation.

Mr. Cole. Yes.

Mr. Watkins. At this point, Mr. Chairman, I should like to make it clear to the subcommittee that I am appearing here in my capacity as Director of the Energy Resources Study and that neither my testimony nor that of my associates involves any commitment as to the relationship of H. R. 7372 to the program of the President.

The President has, of course, already expressed himself in the letter to Chairman Lea of this committee, which you have referred to. And it was there noted, I believe, in this letter that the President asked that the bill be introduced for two purposes; one, in order that the petroleum investigation of 1934 might be brought up to date, and, two, with a view to the enactment of suitable legislation.

Mr. Chairman, I have a statement which it will take me about 12 minutes to read. I would like to have the privilege of reading that statement, because I think it will give you a general indication as to the scope of this testimony. Of course, I will remain available for questioning along with my associates. The papers by Mr. McLaughlin and Mr. Lindsly will require, each, about 30 minutes.

Since we are concerned here with conservation of oil and gas, it is in point first to define the term as it was employed in the Energy

Resources Study. Conservation does not mean abstinence from use or hoarding. Rather the term means wise use; that is, the efficient use of our petroleum resources in the interest of the national welfare, the avoidance of unnecessary waste in production and utilization, and the safeguarding in economic health of the industries and populations on which we rely for the development of these vital resources.

As regards the extent of our energy resources, the National Resources Committee pointed out that although we have a relative abundance of mineral fuels in comparison with the rest of the world, our supply of the superior fuels—higher-grade coal, petroleum, and natural gas—is sufficiently limited that sound public policy requires their conservation or wise use. Our reserves were stated briefly as follows:

> (*a*) Coal of all ranks, 3,000 billion tons, or the equivalent of 2,500 billion tons of bituminous coal, in comparison with 1937 production of about one-half billion tons and accumulated production through that year of 23 billion tons.
>
> (*b*) Petroleum in proven natural reservoirs, 15 billion barrels, in comparison with 1937 consumption of one and a quarter billion barrels.

The latest estimate of the American Petroleum Institute is somewhat higher than that, although it might be noted that certain other estimates submitted after the publication of this report are somewhat lower.

> These proven reserves are equal to about 4 billion net tons of equivalent bituminous coal.

Note the figure, 4 billion net tons of equivalent bituminous coal.

> (*c*) Proven natural-gas reserves, from sixty to one hundred trillion cubic feet, in comparison with 1937 consumption of about two and one-third trillion cubic feet. The reserve is equivalent to three or four billion net tons of bituminous coal.
>
> (*d*) Recoverable oil from oil shale has been estimated at 92 billion barrels, or the equivalent of 21 billion net tons of bituminous coal. This oil, be it noted, is recoverable only at a cost far above the present cost of natural reservoir oil.

It will be noted at once that the ratio of reserves to annual consumption is vastly greater for coal than for oil, about 5,000 to 1 against about 12 to 1, or 14 to 1. Nevertheless, the National Resources Committee noted the need for conservation of coal as well as oil, particularly when it is remembered that about half our coal reserves consist of low-grade coals and lignite; that 70 percent of the total lies in the semiarid plains and in the Rocky Mountain region, far from centers of population; and that 85 percent of our present production is from the 30 percent of the reserves east of the Mississippi. Although some present estimates of proven oil reserves are higher than those cited in the study—and some lower—and although discovery has recently more than kept pace with consumption, present knowledge suggests that the resource is distinctly limited. Twelve years or fourteen years or two or three or four times that figure is a short period in the life of nations. Moreover, it must be noted that the curve representing the number of years' consumption in sight, i. e., the ratio of proven reserves to current annual consumption, has shown a downward trend over the past 40 years. My recollection is that the ratio of proven reserves to annual consumption in the first decade of this century was from 30 to 40 times the annual consumption, whereas at the end of 1938 the reserves were roughly 14 times annual consumption.

Mr. WOLVERTON. What period of time does that comparison cover?

Mr. WATKINS. Roughly, it covers the years in this century. There has been a tremendous increase in consumption, and undoubtedly there will continue to be a great increase in consumption.

To maintain our present position we shall have to discover more than a billion barrels a year—and consumption is rapidly growing. However much oil we may have, it must be remembered that every barrel of oil lifted to the surface or wasted is so much wealth drawn from nature's storehouse. Even if we had a hundred billion barrels of oil, it would be sheer profligacy to waste one barrel of it if that waste could be avoided. The National Resources Committee pointed out in the Energy Resources Study that the rank of petroleum as a source of energy, its vital importance in national defense, its vulnerability to wasteful forces in exploitation, and its comparatively small reserve in relation to the high rate of withdrawal, place this commodity in a unique position among the natural resources. After our natural reservoir oil is exhausted or after the shortage became serious, we can turn to oil made from coal, to oil shale, or, to a limited extent, to alcohol from vegetable matter, but at much higher costs. Although no alarm need be felt over the possible break-down of a motorized civilization, we may well be concerned over the higher costs that we would have to pay and at the prospect of handicaps in international competition.

Although my colleague, Dr. McLaughlin, will present a discussion of wastes of capital and of resources, it may be noted here that their order of magnitude may be tremendous. Thus it has been estimated that waste of natural gas may equal the amount consumed. Further, the universal application of the best engineering methods might in many fields double the ultimate percentage of recovery. Moreover, such methods, by making maximum use of reservoir energy for lifting the oil, would save great amounts in pumping costs. And again, scientific unit control of oil pools might very well reduce by 50 percent or more the number of wells necessary to be drilled. Incidentally, it may be noted that we have drilled in this country almost 1,000,000 oil wells, of which about 380,000 are now producing. New wells are being drilled at the rate of 25,000 to 30,000 a year. Specific examples of unnecessary drilling have been cited by a previous witness [Mr. H. C. Miller], and others will be stated by my colleague.

I wish it distinctly understood that these references to waste in the petroleum industry imply no criticism of the industry. In fact, the improvements in the efficiency of the industry's processes and methods have been little short of phenomenal. Rather, it must be emphasized that these major wastes stem from the incompatibility between the technology of oil and gas on the one hand and the industry's economic and legal pattern on the other hand, chiefly the multiplicity of ownership and operating units and the rule of capture. Scientific unit control is the technical ideal, making for both minimum costs and maximum recovery, but this technical ideal has been unobtainable within the legal framework built on the rule of capture. Thus, if we must assess the blame for the grave waste of capital and of irreplaceable resources that has obtained in this industry, fairness requires that we lay the blame on the doorstep of government, including the courts, since government must determine the legal framework within which an industry operates.

The basic conclusion of the National Resources Committee in the Energy Resources Study was that conservation in this industry means scientific management of oil and gas pools. The committee noted that in many States the courts have already modified the rule of capture by proration laws, under which a landowner can recover only a certain amount of oil within a given period, by well-spacing regulations, and by compulsory integration of interests within drilling units. Although the right of capture has been modified somewhat, it needs, in the words of the National Resources Committee, to be completely displaced by a thoroughgoing law of ownership in place, which would allot to each producer that proportion of the oil and gas in the common reservoir which underlies the land he owns or controls. The committee concluded that the economic advantages of unit operation and scientific management of oil and gas pools are so overwhelming and so generally approved by technicians that some legal device of providing for their adoption and enforcement will surely be forthcoming as the threat of exhaustion becomes imminent. It is clear that no insurmountable technical obstacles stand in the way.

Here is a clear case in which the public interest in conservation of a limited resource is identical with the long-term interests of all groups concerned, consuming States, producing States, landowners, lease interests, operators alike. Unfortunately, however, in almost every situation it will be found that some one operator or some one landowner or even some one State will find it to his or its selfish interest to refuse to cooperate. And so long as one interest insists on following an individualistic policy, they all must do so. It is for that reason that resort must be had to public authority, State or Federal, to require all members of the group to work in unison in order to protect the interests of all producers drawing from a common reservoir.

It was noted by the National Resources Committee that the interest of the public in petroleum revolves around the central problem of maintaining an adequate supply at a reasonable price as long as possible. The National Resources Committee's recommendations with respect to petroleum were made in accordance with that public interest. Thus the committee recommended that the Federal Government should cooperate with the oil-producing States and the petroleum industry in the establishment of minimum standards for production designed to prevent waste and to secure wise use of this unique resource. It was reiterated by the committee that the purpose of such standards should be to secure the benefits of a continuous stream of reasonably priced liquid fuel for as long a period as possible for the national defense, for the people as a whole, and for all the States, both oil producing and non-oil-producing. The committee felt that the change from the present system does not need to be drastic, although more uniformity and better coordination are imperative. It was recognized also that the development of minimum standards for the production of oil and gas designed to further the wise use of these resources is a complex problem, and that it would be a time-consuming process which would call for cooperation with State regulatory agencies and with the representatives of the industry.

At this point, Mr. Chairman, I should like to make more or less of a personal statement. Both my training and my experience have led me to think in terms of long-time trends and long-range objectives. Moreover, I have been impressed with the validity of the philosophic dictum that in the long run no force can withstand an invasion of ideas; that a principle which is philosophically and scientifically sound is eventually irresistible. As an example germane to these proceedings, I will hazard the prediction that scientific unit control is a principle so sound in theory and so overwhelmingly advantageous in its economic effects that in the long run it is bound to prevail. The only question in my mind is how long the process will take; how long it will be before the collective intelligence of our Federal and State Governments is equal to the task of removing the obstacles that stand in the way of this principle. And let me remind you again that only government can remove these obstacles, because they inhere in the legal framework that government has constructed for this industry. Fortunately, it may be noted that there are forces operating within the industry and significant voices being heard within the industry which in time will force the hand of government. Thus the question is whether the executive, legislative and judicial branches of our Federal and State Governments will be pushed and dragged into action or whether they will recognize the obligation of leadership and accelerate the movement of those constructive forces which are even now at work within the industry itself.

Finally, I should like to sum up the import of the findings of the National Resources Committee study, as follows:

1. The grave waste of capital and of irreplaceable resources that obtains in this industry inheres in the economic organization of the industry, e. g., multiplicity of ownership and operating units, and the legal framework, e. g., the rule of capture, within which the industry must operate. Consequently, responsibility for this waste must be assessed against us all collectively, that is, against government, including the courts, since government must determine this framework.

2. The central aim of public policy toward conservation of petroleum should be to maintain an adequate supply at a reasonable price as long as possible.

3. To pursue that aim it is essential that public authority be invoked to assure that oil and natural gas be produced by such methods as will avoid waste of these unique resources.

4. The technical device for assuring avoidance of waste of these resources is scientific unit control of geological structures. The application of such scientific unit control depends on the complete displacement of the rule of capture by a thoroughgoing law of ownership in place which would allot to each claimant his equitable proportion of the oil and gas in the common reservoir which underlies the land he owns or controls.

5. The National Resources Committee in its Energy Resources Study recommended that progress toward the goal of conservation could be made through the development of national minimum engineering standards for the production of oil and gas, such standards to be worked out in cooperation with the oil-producing States and the industry.

6. The inherent logic of this problem is one which calls for the exercise of Federal authority, tempered with recognition of the mutual interests of the States and the Federal Government through cooperation in the development and enforcement of minimum standards. Only the Federal Government has jurisdiction commensurate with the scope of this problem, and surely at this stage it does not need to be argued that the elimination of grave avoidable wastes of such an essential resource is a proper field of Federal interest.

Now, Mr. Chairman, I do not know what will be the pleasure of the subcommittee. This has been organized as a group presentation, and my preference would be that you permit Dr. McLaughlin and Mr. Lindsly to present their statements. If that is not your pleasure, then——

Mr. COLE. Before you proceed, Mr. Wolverton wants to ask a few questions.

Mr. WOLVERTON. Doctor, throughout your statement emphasis has been laid upon the necessity of changing the law of capture to accomplish the purposes that you think are necessary to properly conserve our oil supply.

Did your committee give any study or consideration to the legal problem that is involved in making that recommendation effective?

Mr. WATKINS. Well, I might say that there was some discussion of the changes that have already been made in the rule of capture through State proration laws, and well-spacing rules, and compulsory integration of drilling interests within drilling units in certain of the States. Something of the sort was discussed in some of the staff reports, but in general we did not attempt to deal exhaustively with the legal problem.

Mr. WOLVERTON. It seems to me that the problem before this committee is not merely to inquire whether your recommendation is justified, but assuming that it is justified, how far can it be accomplished by Federal legislation?

In the statement you have just made you have used very strong language to the effect that—

> Only the Federal Government has jurisdiction commensurate with the scope of this problem.

From such recollection as I have at this time, from a consideration of the problem as it was presented to us in 1934, it seems to me that the language you have used would not necessarily be justified by the opinions that have been rendered by the courts.

Mr. WATKINS. May I call your attention also to the statements made concerning the necessity for cooperation between the Federal Government and the States, each in its respective sphere?

Mr. WOLVERTON. I appreciate the fact that you have pointed out that the exercise of Federal authority should be tempered with recognition of the mutual interests of the States and the Federal Government through cooperation in the development and enforcement of minimum standards; but you point to this idea, so to speak, from an engineering standpoint, but give no consideration to the legal difficulties that may be involved in making it effective.

For that reason I am asking whether the Resources Committee gave the very important legal phase of the question any consideration or made any reference to the legal decisions that now prevail.

Mr. WATKINS. You will find a discussion of that problem in the chapters by Dr. McLaughlin in that study on the conservation problem in the petroleum industry, but I think it ought to be said that in general the National Resources Committee did not conceive it to be the function of that Committee to go into the legal ways and means. We were concerned with the problem of conservation and what ought to be done.

Mr. WOLVERTON. Of course, after all, that is an important point, because if we start with the assumption that it is desirable, it becomes necessary to consider whether it can be legally accomplished. It seems to me that until you have given that question particular study and are prepared to present to the committee the authority that would enable us to do the thing that is considered desirable, the case has not been made complete.

Mr. WATKINS. I might say that the subject of unit operation will be discussed by Mr. Lindsly, and also by Dr. McLaughlin, and I think you will get some indication as to what has been done in the various States. My job here is not to outline the legal means. My responsibility is to summarize this report and to indicate what we think ought to be done.

Mr. WOLVERTON. I am not seeking to place any responsibility upon you that is undue. I am merely inquiring whether the committee, of which you are a part, had any legal phases of this under consideration and presented by those who were in a position to assume responsibility and speak of the law as is, and whether it would sustain the recommendations which you have made.

Mr. WATKINS. Well, as I indicated——

Mr. WOLVERTON (continuing). In other words, was your study merely one from an engineering standpoint, or did it take also into consideration the other very practical phase of whether there can be legal justification for doing the thing that you recommend.

Mr. WATKINS. We did not go into an extended legal discussion of the evolution of the law; but enough, I think, was stated in certain of the staff reports to indicate that the law has evolved a long way already and that it is not a great step from what has been done to what needs to be done.

Mr. WOLVERTON. Well, if you have any authority of a legal character that would justify the statement that you have made that "only the Federal Government has jurisdiction commensurate with the scope of this problem," why, I would be very glad to have you, at your convenience, present that to us.

Mr. WATKINS. My only point there was that only the Federal Government has jurisdiction over all of the 48 States, and it may well be that there will be a great discovery of oil in Nebraska, or Mississippi, or some other State which does not have a conservation law.

What authority is there except in the Federal Government to say in advance that conservation legislation must be enacted?

Mr. WOLVERTON. Of course, we all appreciate the fact that in some matters the Federal Government does have jurisdiction separate and apart from the 48 States; but it does not necessarily follow that because there is a Federal Government that it can legislate in all particulars in a way that would be binding upon the States.

Now, the law of capture is a very moot question. I have so understood from my previous reading on the subject, and previous consideration given to it by this committee. It created a doubt in my mind as to how far the Federal Government can go or to what extent the States can go.

The States, as a matter of sovereignty, have contested in all of our hearings the right of the Federal Government to assume absolute jurisdiction as you have indicated here they have a right to do.

Mr. WATKINS. May I note that that is not a statement of principles of constitutional law; it is merely a statement that the scope of this problem is Nation-wide and only the Federal Government has legal powers over the whole country.

Mr. WOLVERTON. I agree with you that it is a Nation-wide problem, and it may be that I am not justified in attaching to your statement the importance that it seemed to carry when you said that "only the Federal Government has jurisdiction commensurate with the scope of this problem."

Mr. WATKINS. Commensurate with the national scope of this problem of conservation. That is what that statement means.

Mr. WOLVERTON. As a member of the committee, I am greatly interested in the legal phases of the question, because after all, whether a recommendation is worth while, depends upon whether it is possible of execution under a law that Congress would enact.

Mr. WATKINS (interposing). Well, I think my proper answer to that——

Mr. WOLVERTON (continuing). If there is any limit to our jurisdiction, we should know it. If there is no limit to our jurisdiction, as a Federal legislative body, we should know that.

Mr. WATKINS. I think my proper answer, Congressman Wolverton, is that I am not a lawyer. I am not an expert in constitutional law. I have merely attempted to state this problem of conservation as I see it, and others will have to deal with the legal problems.

Mr. WOLVERTON. I appreciate that fact, Doctor. I only asked you as a member of the Energy Resources Committee, whether that committee had before it legal opinions that would justify the statements that you have made.

Mr. WATKINS. Do you want me to pursue that; do you intend that as another question to me?

Mr. WOLVERTON. No; I was just stating the purpose of my inquiry, not expecting that you, if you are not a lawyer, would be able to answer the strictly legal questions. I merely inquired to secure advice whether the committee did have before it those who were trained in legal matters, and who were able to give an opinion that only the Federal Government has jurisdiction commensurate with the scope of the problem.

Mr. WATKINS. Well, may I just say this, Congressman Wolverton, that, in my opinion, the National Resources Committee would have been justified in making a recommendation even though the most competent legal counsel in the country had assured them that that recommendation could not be carried out without an amendment to the Constitution, because within their province as a planning agency it would still be their responsibility to say what ought to be done.

Mr. WOLVERTON. I am in perfect accord with you on that. I merely wanted to carry it further and see whether the recommendation is possible of being made effective by Federal legislation.

Mr. WATKINS. Well, my opinion is that it is possible, but that is the opinion of a nonlegal mind.

Mr. WOLVERTON. I understand, and I accept it that way.

Mr. COLE. You are familiar with the provisions of H. R. 7372, are you?

Mr. WATKINS. In a general way. I have read it.

Mr. COLE. Are you familiar enough with the provisions of that bill to say whether it embodies the recommendations you present in this report?

Mr. WATKINS. First I ought to say, Mr. Chairman, that I did not draft that bill; I did not have anything to do with its drafting. Moreover, I am not a lawyer. I do not know how these provisions ought to be written into law. I cannot pass judgment on the legal phraseology. I can say this, that the National Resources Committee has recommended the enactment of a Federal conservation law and the enactment of minimum engineering standards designed to eliminate waste, and has called for the development of such standards in cooperation with the State regulatory authorities and the industry, and has suggested also that the problem, both as regards the development of these standards and the enforcement of these standards, ought to be worked out on a cooperative basis to respect the particular spheres of the State Governments and the Federal Government.

Insofar as H. R. 7372 attempts to do those things, I think it is aiming in the right direction.

I do have the feeling, however, that there is not a sufficiently strong indication of the possibilities of encouraging and requiring cooperation in the development of oil pools. I have not had the bill explained to me in detail as to its purposes and effects and intents by one who is technically qualified in that field, by one who has been concerned with the regulatory functions; but my impression is that it does not go far enough in that respect.

I might say also that since I am not a lawyer, I am not in position to write the formula for this State and Federal cooperation that the National Resources Committee has recommended, both as to the formulation of standards and as to the enforcement of standards. But I do want to say this, that I wholeheartedly support the objectives of that bill.

Mr. COLE. The standards set out in the bill are supported by you?

Mr. WATKINS. You mean to say the engineering standards, the definitions of waste?

Mr. COLE. Yes.

Mr. WATKINS. Well, again I think that is a technical question. The bill has not been referred to me for my criticism or, so far as I know, to the National Resources Planning Board. If it were referred to me for my criticism, I would want to get a group of competent engineers and geologists to review those standards and to consider them in the light of the standards that have been developed in the best State conservation laws, and thus to see whether there are any significant omissions, or whether some of the State standards of waste or definitions of waste are adequate.

Mr. COLE. All right, sir.

Mr. Wolverton. Doctor, you have made reference many times during your statement to the importance of having a unit system of recovery, as a means of precluding waste.

Does this bill make possible that program?

Mr. Watkins. I just indicated a moment ago that I am inclined to question whether it goes far enough in that respect, insofar as the recommendations of the National Resources Committee are concerned.

Mr. Wolverton. The reasons that I pursue this thought, there has come to my attention, through reading the magazine and newspaper accounts of speeches that have been made, that there is objection upon the part of the States that the enactment of this bill would in the final analysis enable the Secretary or the Commissioner to make findings that would become effective within the State, therefore having in mind the importance of this unit system or program which you laid some emphasis upon, I am inclined to assume that that would be one of the policies that might be found necessary by the Commissioner or the Secretary, and such being the case, would it be possible for the Secretary or the Commissioner under this bill to enforce that program in a State where the program has not been adopted, nor had legislative approval by the State.

Mr. Watkins. I do not know whether you are asking that as a question in constitutional law or just what; but I think——

Mr. Wolverton. No. You have already qualified yourself as not being able to pass on legal questions. I am asking it from a practical standpoint now, whether in your study and in your conferences with your colleagues you have had it made known to you that the enactment of the bill would have that effect.

Mr. Watkins. The very idea of minimum engineering standards which would be enacted into law by the Federal Government would indicate that the intention was to have those apply wherever oil was produced in the United States.

Mr. Wolverton. If I understand you correctly, if a State did not approve of the particular program of unit control, that would be fixed by the Secretary or the Commissioner, under this bill, then this bill would have the effect of giving authority to the Federal agency to enforce it in the State.

Mr. Watkins. Why, I should assume so, yes; if it does set up minimum standards and there are no standards in a given State, then I assume under that bill it would so happen.

Mr. Wolverton. You understand that I am not asking you to express a legal opinion based on the phraseology of the bill, but my question is whether it has come to your knowledge as one of those interested in this subject and having made a study of it, whether this bill if enacted into law would carry out that thought.

Mr. Watkins. I suppose the answer is obvious, is it not?

Mr. Wolverton. What is the answer?

Mr. Watkins. That if the law aims at the setting of minimum standards, and if there are no standards in a given State then, presumably, those minimum standards would apply.

Mr. Wolverton. Have you heard the question of unit control or the unit program discussed? I am just using that as an illustration of one of the policies that might be inaugurated. Have you heard it discussed in such a way as to say, "Well, if we get that law we can put that into effect?"

Mr. WATKINS. I have not.

Mr. WOLVERTON. Well, that is what I want to know. I want to see whether this bill will accomplish what you wish to accomplish with reference to unit control.

Mr. WATKINS. But, let me repeat again what I said a moment ago. I did not draft the bill, and I have no responsibility for that bill.

Mr. WOLVERTON. I understand that; but I am assuming that in a group that is seeking to do a certain thing, that it would certainly come to your attention, whether the legal authorities had said to you, "This bill will accomplish the thing that you engineers wish to do."

Mr. WATKINS. I might call your attention to some statements that Mr. Soyster made this morning, that if you do have the authority to determine certain minimum engineering standards, then you can practically set the criteria that would be set under unit operations.

Mr. COLE. Doctor, is it correct to say that this bill does not adopt unit operation theory or any other?

Mr. WATKINS. I think there is nothing specific on unit operation or scientific unit control.

Mr. COLE. Is it possible in the operation of the bill if it should become a law, for that to be brought about, that is, for the Commission to cooperate with the States in working out better ways for preventing waste?

Mr. WATKINS. I am not competent to answer that question.

Mr. COLE. All right.

Mr. WATKINS. May I say, Mr. Chairman, that I had planned on Dr. McLaughlin coming on as the second witness, but since Mr. Lindsly has to be in Federal court in New York tomorrow, perhaps he ought to speak as the second witness.

Mr. COLE. All right; we will hear Mr. Lindsly.

## STATEMENT OF BEN E. LINDSLY, SENIOR PETROLEUM ENGINEER, SECURITIES AND EXCHANGE COMMISSION, WASHINGTON, D. C.

Mr. COLE. All right, Mr. Lindsly.

Mr. LINDSLY. My name is Ben E. Lindsly, senior petroleum engineer, Securities and Exchange Commission, Washington, D. C.

I appeared before this committee 5 years ago and I have had a great deal of pleasure and interest in reviewing some of the testimony that was given before the committee relating to unit operation. I have prepared a statement here of some 60 pages, which I do not intend to read. I intend to go through it and try to talk on the high lights and, if it would assist the committee in any way, I have copies which I could give to you for you to follow.

Mr. COLE. We will be very glad to have them now.

Mr. LINDSLY. All right, Mr. Chairman.

Mr. COLE. All right, you may proceed.

Mr. LINDSLY. Well, Mr. Chairman, the index covering the 1934 report of your committee records 48 separate and distinct references to some phase of unit operation or unit control of oil pools. A perusal of these references given in your index indicates that and I have found that, without a single exception, every witness who expressed his views on the subject stated in effect that the concept of unit operation was ideal from the standpoint of efficiency, economy, and conservation of an irreplaceable natural resource.

And in going over some of the questions and answers, particularly some of the questions, I know that the committee itself is well informed on this subject and I do not intend to completely review this testimony, because I am quite sure that you remember it quite well, although I will make a few references to some of the more important testimony and opinions of leaders of the industry.

The meaning of unit operation and its origin and history I will pass up, because I know that you know it and it would be taking up time to go over that.

I will call attention first—this is on page 5 of this statement relating to the statements given by Gibson which explains that—

> In Great Britain, where petroleum has not yet been discovered in commercial quantities, the Petroleum (Production) Act of 1934 contains a clause whereby unit development may be enforced "in order to secure the maximum ultimate recovery of petroleum and to avoid unnecessary competitive drilling."

The advantages, certain of the advantages of unit operations in foreign fields, are referred to by Gross in an article in the Oil Weekly. He shows where 14 wells producing in the Kirkuk field in Iraq, I think, in the Near East anyway, produced in 1935 29,000,000 barrels of oil from 14 producing wells. Comparing these results with Yates oil field, a field in which every oil-production man, and engineer, points to with pride as effective cooperation, we find that in 1938 Yates produced 6,728,426 barrels of oil from 549 wells, or an average of 33.6 barrels per well per day, whereas the daily average production per well from the 14 wells in the Kirkuk field in 1936 was approximately 5,720 barrels.

The writers do not mean to imply that the daily production of 18,441 barrels from the Yates field could be obtained from 3 wells operating at approximately 5,720 barrels per day, because the character of the producing horizons probably differ even though both produce from limestone. Regardless of these differences, however, it is undoubtedly true that the total daily production of 18,446 barrels could have been obtained with one-tenth the number of wells had complete unit operation been in effect.

Now, as I say, these 14 wells produced at the rate of 5,720 barrels per day, perhaps 200 times as much as the average well in the Yates field.

Now, I am going to read a little, a few expressions that were given to this committee by leaders of the industry back in 1934.

Mr. L. V. Nicholas, president, Warner-Quinlan Co., New York, N. Y., on page 534, volume I, says [reading]:

> Under the Doherty plan this crazy [law] of capture gives place to a scientific and orderly procedure that gives definite and possessive property rights to each owner's oil as it lies underground and in place, and an orderly production formula gives full protection to each and every owner's interest—and what was formerly a mad scramble to steal the other fellow's oil before he steals yours is forced to become an orderly, sane, and sensible business transaction.

Then, Mr. W. S. Farish, chairman of the board, Standard Oil Co. (New Jersey), made quite a comprehensive statement, volume I, page

672, in his fourth item. I will not read the whole statement, but his fourth item I will read:

> Fourth, when it developed that voluntary efforts for unitization and cooperative control were not meeting the situation because of minority opposition, the company supported proposals for legislation in which police power of the States would be invoked to secure conservation and production control.

Mr. Farish's statement throughout favored unit operation.

Now, on page 1251, volume II, Mr. C. B. Ames, chairman of the board, the Texas Co.—he did not testify directly before the committee. He was quoted in that section of the report that Mr. Miller and I made, but, here is Mr. Ames' statement, and I am reading at the bottom of page 11 of this statement [reading]:

> An oil pool is a unit, and obviously ought to be operated as such. Diligent efforts are being made to bring about unit operation, and substantial progress is being made. This movement has and is entitled to have the support of the industry. It is so obviously sound that there is practically no division of practicability. Surface ownership does not coincide with the boundaries of the oil deposit, and, therefore, there are numerous surface owners entitled to penetrate the oil sands. Each one desires to recover as much oil as possible, and it cannot be known in advance how much is under the surface of each owner. Some surface owners need the oil in their business, while others do not. Different leases have different drilling operations. The royalty owners are an important part of the picture. This diversification of interest is an obstacle in the way of unit operation. Under the law, a surface owner has the right to drill on his own land. This is a right of which he cannot be absolutely deprived. He cannot be forced into unit operation, and, therefore, unitization must rest upon consent and not compulsion. As the diversity of interest sometimes prevents consent, progress in unitization can only be made gradually and by persuasion.

Here is an important statement on page 1415, volume III, by Wirt Franklin, president, Independent Petroleum Association of America, and president, Franklin Petroleum Co., Oklahoma City, Okla.

Speaking of unit operation, Mr. Franklin said [reading]:

> * * * whenever a majority in acreage and in numbers in a pool of oil agree upon a planned development, there should be machinery provided to make that plan effective and to compel the unruly minority, sometimes only one individual, to comply with that planned development in order to prevent the waste incident to the past methods, to save the gas energy, to prevent the waste of gas, to so withdraw the oil as to get the greatest ultimate recovery, and to prevent excess production in times when there is no demand for it; * * *.

On pages 1577 to 1580 of volume III, Mr. Earl Oliver, of Ponca City, Okla., testified—and I consider Mr. Oliver one of the best-informed students of unitization of oil pools in the United States. He says [reading]:

> This destruction of an important natural resource and periodic demoralization of a vast industry can be halted only by readjusting oil and gas law until it promotes oil-field-development practices suited to the products handled. To indicate the readjustments that are necessary, it is desirable to summarize the elementary principles, both of oil and gas accumulation and of oil and gas law * * *.
>
> Because of the nature of oil and gas deposits, it is apparent a national unity of action must be developed in their exploitation.

I think this statement which I have recorded on page 14 of my manuscript by Henry M. Dawes, president of the Pure Oil Co., Chicago, Ill., hits the nail on the head. It appears in volume III, page 1735. Mr. Dawes said [reading]:

> From the standpoint of conservation, and every other standpoint, unitization is very effective. It is very difficult to put into effect, but once in effect, I

think it is the greatest measure of conservation and economy that could be devised.

Mr. Wolverton. Will you permit me to interrupt you?

Mr. Lindsly. Yes, sir.

Mr. Wolverton. What is the difficulty that he refers to when he says that it is very difficult to put into effect?

Mr. Lindsly. I think it is well put in a paper by Mr. Don Knowlton, of the Phillips Petroleum Co., who read a paper at the American Petroleum Institute meeting in Oklahoma last April. I will read his statement because it really answers your question, I think, very effectively. I have it here.

Here is what Mr. Knowlton says [reading]:

> It is not difficult to understand why until the last 10 or 12 years operators were opposed to this plan. Oil men at this time were the most rugged of rugged individuals, and the wildcatter gambling spirit was thoroughly instilled in them. From their very nature it can be seen that they would have no desire to exchange this game of chance with the possibility of big, quick, profits for stabilized business under unit operation. Considering this from both the gambling spirit and the fact that the price of oil was approximately $3.50 a barrel; that there was a ready market for all of it; that taxes were low and that wells were shallow; it is not surprising that little thought was given to conservation and cooperation. The oil business was too busy making money. Few have time to consider the plan of unit operation, but the few who did consider it became staunch supporters of the plan; and when such men as J. Edgar Pew, Judge W. P. Z. German, and W. N. Davis joined in thought with Mr. Doherty, then others were interested listeners.

I would think just the American spirit of wanting to do what they want to do and get their money, if they can, and make their profits, and have the fun of making it in a period of 1 year rather than 10, is probably the best answer to your question.

Now, relating to J. Edgar Pew's statement, which appears in volume IV, at page 2033, he states [reading]:

> If possible, the law as to "capture" be repealed and in its lieu a bottom-hole pressure-acreage basis of recovery be established.

Now, Mr. Pettengill, I believe, asked this question:

> It is your judgment, is it, Mr. Pew, that the law of capture is the worst thing that the oil industry has to go up against?

And Mr. Pew answered:

> That is correct.

I here quote Wallace E. Pratt, vice president, Humble Oil & Refining Co., Houston, Tex., volume IV, pages 2156–2160, with reference to waste, and particularly he was speaking of the Panhandle. He says [reading]:

> Uncontrolled production is notoriously and inevitably wasteful production * * *.
>
> The (Panhandle) is, I think, an example of the waste that comes from uncontrolled production * * *.
>
> I would operate the field as a unit.

On page 2459, volume IV, Mr. Axtell J. Byles, president of the American Petroleum Institute, New York, N. Y., says [reading]:

> The industry is not ready to adopt unit operation of pools as such. A great many people are afraid of that yet, but I venture the prediction that in the long run that is the way all pools will be developed and produced, because of the fact that it is the most efficient way to produce them.

The only question that comes to my mind is just how long a run that is going to be. It might be a pretty long run.

Mr. F. E. Heath, petroleum engineer, Sun Oil Co., Dallas, Tex., volume IV, page 2470——

Mr. Cole. Mr. Lindsly, we have copies of this statement before us, and it seems unnecessary to go into detail.

Mr. Lindsly. Well, that is about the last. Mr. Heath is about the last one that I wished to quote. Well, anyway——

Mr. Cole. We are very much interested in the studies you have made of the hearings, and it is interesting to have it brought up in parallel columns in these hearings, I think.

Mr. Lindsly. I simply want to review what I considered were the high points, so that your mind would be reflected on the thoughts and quotations, and so that whoever might go over this would have a little backlog without having to go through the four volumes and pick this out as I did.

Mr. Heath is honest and a prominent petroleum engineer—a thoroughly honest man—and I am satisfied his endorsement of unit operation is purely from the standpoint of the highest motives. I would think if he had his own tract to evaluate in any unit scheme that he would bend over backward not to give himself too much.

I will just call attention to the fact that the opinions of these leaders given in 1934 with regard to the benefits were always subject to the proviso that such method of production could be put into practical effect.

Now, I think it is pertinent to find out in what way, if any opinions have changed during the last 5 years. I have tried to see if the two leading petroleum associations in the United States, the Independent Petroleum Association of America and the American Petroleum Institute, have ever gone on record as endorsing unit operations. I cannot find that they have.

Mr. Wolverton. Mr. Lindsly, before you leave the point that you have been making with reference to unit operations, wherein you have quoted from many different individuals, in view of the fact that they would seem to approve some such system, why is it that it has not been put into effect by these same individuals in the fields that they control?

Mr. Lindsly. I think that is a good question. I do not know of any fields where they control, but where they have controlled the fields they have done it. There is no question about that.

Mr. Wolverton. That is where there is no conflicting rights.

Mr. Lindsly. That is correct. They always do it, I can almost say.

Mr. Wolverton. I have in mind a field that was shown to us when we made our visit—I think it was in Oklahoma—where we were shown a field of that character. It was laid out effectively from that standpoint.

Mr. Lindsly. Yes.

Mr. Wolverton. The fact that they all approve of it, and yet the further fact that it is ineffective generally, creates in my mind the thought that there is an existing difficulty.

Mr. Lindsly. It creates in my mind that there is a difficulty, too.

Mr. Wolverton. What is that difficulty; is it legal; is it a difficulty that can be corrected by legislation of the character we have before us at the present time, or is it a difficulty that must be corrected by State legislation?

It is very helpful to understand in a general way what would be a perfect system, and what is desirable, but after all we must look at it from a practical standpoint and determine how far this committee, as a representative of a Federal legislative body could recommend legislation to that body to make it effective.

Mr. LINDSLY. Mr. Wolverton, those same questions have come up to me. It is hard to reconcile a fact that such comparatively little progress has been made on a project, on a plan of development, that is universally acknowledged as being the ideal. I am going to point out where—a little later in my paper—where there have been very definite efforts made and some accomplishments but not commensurate with the problem. Frank Phillips, chairman of the Phillips Petroleum Co. and his whole organization have been instrumental in unitizing a number of projects and——

Mr. WOLVERTON. Well now——

Mr. LINDSLY. Excuse me.

Mr. WOLVERTON. You have made reference to Mr. Phillips. Right on that point, as to how far he agrees with this bill as being desirable legislation, let me read what he said in his prepared statement [reading]:

> As to pending legislation, I am convinced that neither the industry nor the public would long tolerate the consequences of its application. The Cole bill is cloaked in a frameless appearing framework of conservation principles, which could easily be used for establishing an incorrect but effective dictatorial form of extensive rule. The only voice that those regulated would have would be the weak and futile opinion of a so-called advisory council.

Now, when you used him to sustain the point that you are making as to the value of a unit system, it would seem as if he does not agree with this bill as being a proper approach to that.

Mr. WATKINS. Mr. Chairman, may I interpose just for a moment? I would like to read into the record a brief quotation from an article by Mr. Frank Phillips, because it bears not only on this general question, but on the question relating to the necessity of Federal legislation which we were discussing just a moment ago.

Mr. WOLVERTON. May I identify the statement of Mr. Phillips to which I refer by saying that the statement from which I was just quoting, appears in the magazine, National Petroleum News, of the October 25, 1939, issue.

Mr. WATKINS. I may say, Mr. Chairman, that I intended to read this statement into the record a while back. I had it over there, but I overlooked it and I will say that it does not make any difference from my standpoint whether Mr. Phillips endorses H. R. 7372 or not. What I am concerned with here is the objectives and principles, and I would like to read into the record a portion of an article in the Oil Weekly for August 14, 1939. It is an article written by Mr. Frank Phillips, chairman of the board of the Phillips Petroleum Co. It had originally appeared in the Mines Magazine, the official organ of the Colorado School of Mines Alumni Association, and this particular quotation——

Mr. WOLVERTON. You say it was previously printed. Where was the article originally printed?

Mr. WATKINS. It appeared in the June 1939 issue of the Mines Magazine and it was reprinted in the Oil Weekly in the issue of August 14, 1939, with this statement [reading]:

> The Oil Weekly is indebted to the author and to the Mines Magazine, official organ of the Colorado School of Mines Alumni Association, for the opportunity of presenting to the oil industry this vital discussion of present and future oil-field economics. The article originally appeared in the fourth annual petroleum edition of the Mines Magazine, June 1939, under the title: "Streamlined science needs horse-sense economics."

Here is the quotation:

> Although the Federal Government already is playing some part in the national petroleum picture through the Interstate Oil Compact, the Connally Act and the Bureau of Mines' monthly estimates of demand, none of these are effective in eliminating racketeering tendencies among the several States. Under such conditions, it would seem obvious that an element of regulation should be placed over the States similar to that which already has been placed over the pools and operators within those States having regulatory legislation. The oil industry, like all other industries, already operates under various elements of Federal regulation. The very oil companies and oil States who now frame their own distorted conceptions of how the Federal Government would use its powers to inject reason into an otherwise chaotic situation, and who then object strenuously to that self-created conception of Federal sanction or regulation, are those who are crying the loudest for Federal control of petroleum imports. Imports are only another factor in national petroleum supply, the same as is the daily production which flows from our own Nation's wells. Only the Government can effectively police import supplies; who else can police our multiple-State supply? Any State that is attempting to play fair and is efficiently producing the Nation's petroleum resources is just as much harmed by lack of Federal influence over the flooding of the national market with oil from wasteful States as it is by the flooding of our domestic market with oil imported from outside the States.
>
> We do not need Government operation or management, but we do need a background of regulation that will enable oil producers to do their own operating in an effective and economical manner. * * * If there is any other agency that can render equity to the national situation, where is it? * * *
>
> It is my conviction that the logic of "the new conception of oil production," as exemplified by unitization and wider well spacing and similar advanced ideas, soon will be universally recognized and applied.

Thank you, Mr. Chairman.

Mr. WOLVERTON. After reading that, how do you explain the statement which I read?

Mr. WATKINS. I am concerned only with the objectives of conservation, and I am concerned only with this principle that you have got to resort in some measure to Federal authority.

Mr. WOLVERTON. But the point that I am making is, assuming that this unit system is desirable—and I am not arguing against your viewpoint with respect to that. I do not want you to think from my questions or to assume that I have any different viewpoint. I am merely inquiring, assuming that you are justified in the emphasis that you place upon unit control, does this bill accomplish it, this bill that we now have before us, namely, H. R. 7273.

Mr. Phillips, whom you have quoted, would seem to believe in the principle of unified control.

Mr. WATKINS. Some method.

Mr. WOLVERTON. And yet he objects to this particular bill.

In view of what you have read to us, could it be assumed he is objecting to it because he is opposed to the principle or that he is objecting to it because of the provisions of this bill?

I am trying to find out from somebody, first, whether this bill would make effective the system that you folks so highly recommend, and if so, could it be made effective against the wishes of a State or the individuals who own the oil fields?

Mr. WATKINS. Well, Congressman Wolverton, it is not my function to explain or defend H. R. 7372. I assume that before this proceeding is over such explanation will be given by others, but it is not my responsibility.

Mr. LINDSLY. Well, Mr. Congressman, I would be interested to be at the meeting when you ask Mr. Phillips that question. I think that is an interesting question to ask him.

Mr. WOLVERTON. I can assure you that while my questions may go along a particular line at this time, I am looking forward to the opportunity of asking the same information from others. I will want their opinion on this important matter.

Mr. LINDSLY. I would like to be there when you ask the question.

Mr. WOLVERTON. In other words, the only desire I have and the only thought that prompts me is to ascertain all possible information pro and con on this subject so that when this committee makes a report it will be on the basis of having all possible information.

Mr. LINDSLY. And I may say that my particular object in quoting the opinions of these men is to show how universally favorable they were to it, to bring the question up in your minds as to why unit operations will be a progressive step forward.

Now, going on, I find that neither the Independent Association of America nor the American Petroleum Institute have, so far as I have been able to determine, ever gone on record as endorsing unit operations as such. It is perfectly true that the presidents of both of those organizations endorsed it, and I also have a report, a copy of a report, from a committee in the Independent Association where the committee reported on unification and unprofitable drilling, and included in this report is the following statement—this is a committee report to the Independent Petroleum Association of America. This committee says [reading]:

> It should also be pointed out that the growing tendency of operators to unitize small tracts into drilling units, and even to unitize their properties into large operating units, is becoming more prevalent than in the past. This practice results in the greater saving in development costs.
>
> Although substantial progress is being made toward eliminating unnecessary wells, it is still one of the main causes for our economic ills in the industry. Operators continue to drill unnecessary wells in large numbers, and the allowable per well is being continually reduced to a level which results in a longer and longer pay out for capital invested.

In June 1936 Axtell J. Byles, president of the American Petroleum Institute stated [reading]:

> Development and operating costs can be reduced and full production obtained by wider spacing of wells and more cooperative development programs, and, where possible, by unit operations.

I quote here on page 18 from the article that Dr. Watkins quoted from.

Mr. COLE. It is not necessary to go over that again.

Mr. LINDSLY. I will not go over that again.

Just recently Dr. Joseph E. Pogue, vice president, Chase National Bank, New York—He is an economist—in his analysis of conservation and proration before the National Economic Committee, Dr. Pogue is reported to have stated that the procedure of unit operation is gradually gaining headway in the business and that the formation of pool cooperatives should certainly be encouraged in every feasible manner, but the progression toward full unitization. while persistent, is slow, because of the principle of deferment.

Now, here is one of the reasons, maybe, Congressman Wolverton, that has deterred the adoption of unit operation. Here is a statement made at the Temporary National Economic Committee hearings, by John E. Shatford and Karl A. Crowley. Shatford is an independent operator of El Dorado, Ark., and Crowley is at Fort Worth, Tex. These men criticized unit operation "from the standpoint of stifling the operator owning small tracts of land and harassment of large operators."

They have made that as their objection to unit operation. That is their criticism. These men, however, offered no criticism of unit operation from the standpoint of efficiency and conservation. It was a question that they thought that they were being stifled.

I might say that the independent operators in Kansas and you might say that the State of Kansas is controlled by the independent and not by the major oil companies, and they are going into unit operations continually. They are going into unit operations which are backed and sponsored by the Phillips Petroleum Co.

So while maybe the independent operators in Arkansas and Louisiana and Texas object to being shackled with a certain kind of systematic control, apparently the operators in Kansas, and I believe also a great many of the operators in Oklahoma, are quite ready and willing to go into unit plans of development.

In a recent report by the Work Projects Administration in cooperation with the Bureau of Mines, the following statement is made [reading]:

> *Unit operation the technical ideal.*—The need for conserving and harnessing the powerful natural forces in an oil or gas reservoir if maximum recovery is to be obtained suggests the desirability of exploiting that reservoir as a single gigantic engineering project.

I will not go on with that statement.

Now I am going to quote a question that Congressman Cole propounded in his address at the tenth annual meeting of the Independent Petroleum Association of America at Fort Worth, Tex. [reading]:

> Four years have passed since the Congress authorized the Secretary of the Interior to require the submission of unit plans when public lands were to be leased for the production of oil and gas. Sufficient time may now have elapsed to permit of some valuation of the merits of these plans and whether they are effective in promoting an increased recovery of oil.

I think Mr. Soyster has already testified regarding that—the effect of unit operations on public lands; but in further answering that question—and I think its importance, so far as national conservation of oil is concerned, is much greater with the privately owned land and the public lands. I am going to refer to a statement by the chief engineer of the Carter Oil Co. relating to the South Burbank field. That is on page 41 of this paper [reading]:

> According to Ivan S. Salnikov, chief engineer of the Carter Oil Co., Tulsa, Okla., an ultimate recovery of as high as 15,000 barrels of oil per acre can reasonably be expected from the unitized development in the South Burbank field de-

veloped entirely on 20-acre spacing. This represents an estimated increase of 5,500 barrels per acre over that of the old Burbank pool, where the maximum recovery was only 9,500 barrels per acre and developed on 10-acre spacing, wide-open flow, and without repressuring. Computed on the 2,300 acres in the South Burbank unitized block, this would represent an additional recovery of approximately 11,600,000 barrels before the properties are completely exhausted. The South Burbank block has already produced 7,000 barrels to the acre, representing an accumulated production to date of about 15,000,000 barrels.

This 7,000 barrels per acre has been produced by flowing, whereas the old Burbank pool yielded only 4,000 barrels per acre by flowing under wide-open methods.

Now, there are certain new things that have come up since 1934. I refer now to the extensive development, and extensive leasing in the Forest City Basin which corners on the four States of Missouri, Iowa, Nebraska, and Kansas. This really presents a hazard to the industry; the hazard of discovering a pool of big reserves.

Mr. COLE. I think it is about time that the committee will have to close this afternoon. You have about concluded your statement, have you not?

Mr. LINDSLY. I might come later. I really have to be in New York tomorrow. I can leave this for introduction in the record.

Mr. COLE. Well, suppose you do that, and the committee will recess this afternoon until Friday morning when we will hear the Secretary of the Interior first and then if there is any time left Friday we will hear the other witnesses. I understand that you will require about half an hour for your witnesses?

Mr. WATKINS. Yes. May we count on some time Friday?

Mr. COLE. I think that we can count on some time Friday after we hear the Secretary of the Interior.

Mr. WATKINS. On Friday morning the Secretary will come first?

Mr. COLE. Is it the understanding, Mr. Holland, that the Secretary will be here Friday?

Mr. HOLLAND. I understand that he will return to the city tomorrow morning.

Mr. COLE. Can he be here Friday?

Mr. HOLLAND. I would not be able to say. I understand that tomorrow is Cabinet meeting day. I will take it up with the Secretary.

Mr. COLE. What time does the Cabinet meet, in the afternoon?

Mr. HOLLAND. Sometimes in the morning and sometimes in the afternoon; usually about 2 p. m., I think. I will speak to the Secretary tomorrow, sometime tomorrow morning as soon as he returns and get in touch with you then, Mr. Cole.

Mr. LINDSLY. May I add one thing to my testimony?

Mr. COLE. Yes.

Mr. LINDSLY. Mr. Steuart here advises me that the Independent Petroleum Association of America is on record in favor of voluntary unit operation, but not compulsory.

Mr. WOLVERTON. Mr. Chairman, may I in that connection, mention a reference to this bill, H. R. 7273, that appeared in a magazine. It justifies what I said a few moments ago. I said that I was under the impression that some were of the opinion that the bill was not satisfactory. What I had in mind was a debate Don Emery of the Phillips Oil Co. had with Mr. George Hill, president of the Houston Oil

Co. This is what was said, as appears in the Petroleum News, issue of October 25, 1939 [reading]:

> The speaker—
>
> Referring to Don Emery—
>
> points out to the members the fact that, if the Cole bill is passed, the States will be powerless to regulate production and that the bill is powerless to relieve any existing ills in the industry. When George Hill began his argument he asked Mr. Emery if he had heard him aright when he pointed out those two facts. And Emery replied in the affirmative, and Mr. Hill said, "Well, why discuss the thing? It is the damnedest thing I ever saw proposed. I see no reason for the prostitution of State rights in order to get a palliative." The applause which greeted those remarks indicated the feeling of the members on the committee.

Mr. LINDSLY. Well, none of them like laws. They do not like to be regulated.

Mr. WOLVERTON. Well, if your statement which you quote from as having been made by these several gentlemen correctly defines their viewpoint, it would seem as if they favor the proposition that you are advancing; but the point that I am making is this, that they do not seem to be satisfied with this bill as a means of making it effective. It is for that reason that I have been inquiring of the witnesses today as to how far, in their opinion, this bill will make the thing which you favor and which you say they favor, effective.

Mr. WATKINS. May I say again, our function is not to defend the bill.

Mr. LINDSLY. I do not see how the bill can accomplish the things that it proposes to accomplish without some kind of unit control of oil fields. It is just impossible; it cannot be done.

(Here follows the full statement filed by Messrs. Lindsly and Dahlgren:)

## UNIT OPERATION OF OIL POOLS

STATEMENT TO THE SUBCOMMITTEE ON PETROLEUM INVESTIGATION, HOUSE COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE, AS AUTHORIZED BY HOUSE RESOLUTION 290, SEVENTY-SIXTH CONGRESS, FIRST SESSION

(By Ben E. Lindsly[1] and E. G. Dahlgren[2])

### INTRODUCTION

The index covering the 1934 report of your committee records 48 separate and distinct references to some phase of unit operation or unit control of oil pools. A perusal of these references indicates that, without a single exception, every witness who expressed his views on the subject stated in effect that the concept of unit operation was ideal from the standpoint of efficiency, economy, and conservation of an irreplaceable natural resource. That it was far superior to the so-called "rule of capture" or to the modifications of this rule by State regulation was not questioned by a single witness.

That your committee recognized the importance of the unit plan of operation and the benefits to be derived therefrom is clearly indicated by the character of the questions various committee members asked the witnesses.

Because of this evident knowledge, the writers of this statement will review the subject only sufficiently to make it intelligible to those who may not be familiar with the committee's previous report, published in 1934 under the authority of H. R. 441, Seventy-third Congress. With respect, however, to new developments and new applications of the unit idea since 1934, the writers will attempt to outline such progress in greater detail.

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## MEANING OF UNIT OPERATION

The meaning of unit operation is explained by Cadman[3] in the following language:

Page 3: "By unit operation or control is meant the operation of any one geological unit by one management responsible to the various owners for the development and exploitation of the unit as a whole, the owners taking their share on the average-content principle. It is practiced in many countries where concession terms permit the taking up of large blocks of territory sufficient to cover geological units, or where geological units are in sufficiently few hands to render cooperation possible and workable. The Anglo-Iranian Oil Co. and Iraq Petroleum Co. may be cited as examples of companies working under the first set of conditions, and the Kettleman Hills North Dome Association as an example of the second set. It is pertinent to state in this connection that in the British Petroleum Regulations of May 15, 1935, issued in relation to the Petroleum (Production) Act of 1934, provision is made for cooperation among lessees of one geological unit, to be effected in the first place by voluntary action among the owners themselves, failing which, compulsorily under a scheme prepared by the Government with, however, the right to arbitration. * * *"

Shades of differences between the terms "unitization," "unit operation," "unit development," and "cooperative development" are explained in the Handbook on Unitization of Oil Pools.[4]

## ORIGIN AND HISTORY

### (1) UNITED STATES

"The early history of unitization is centered almost entirely around one man—Henry L. Doherty. Speaking before the annual meeting of the American Petroleum Institute held at Chicago in November of 1931, Mr. Doherty gave us some idea of the length of time in which he has been interested in unit operations. In his talk he made reference to an argument which he had on this subject in 1895. That was over 45 years ago, and we are only now beginning to appreciate fully the wisdom of unit operation. It would indeed be interesting to hear Mr. Doherty tell the history and progress of this plan which, when first proposed, was deemed so radical."[5]

It was not until 1924, however, that Mr. Doherty made public announcement of this plan. Since that time public discussion of the "Doherty plan" by petroleum engineers and others interested in the oil production has grown to such an extent that in the late 1920's and early 1930's scarcely a gathering of production men could be had without including, either formally or informally, a discussion of unit operation. In its 1930 volume on Petroleum Development and Technology, the American Institute of Mining and Metallurgical Engineers included 12 papers on unit operation, in addition to committee reports and prepared discussions.

The concept of unit operation, whereby development of a pool may take place with complete disregard to surface ownership and boundary lines, but with minute consideration of harnessing and utilizing the forces of nature to the benefit of mankind, has captured the imagination of virtually all of the technical men and others engaged in the production of petroleum during the past 15 years. The fact that unitization of oil pools has made such slow progress in 15 years that probably not more than one-half dozen pools in the United States can be considered 100 percent unitized as to both fee and leasehold interests must be laid to causes other than ignorance. A discussion of some of these causes is taken up under the topics "Divergent Viewpoints" and "Rugged Individualism" on pages 48 and 49.

### (2) FOREIGN

In foreign countries, where conditions of mineral ownership are entirely different from the usual conditions existing in the United States, unit operation was logical. Through the natural evolution of oil-production technique, unit

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[3] Cadman, Sir John, chairman, Anglo-Iranian Oil Co. Third World Power Conference, Washington, D. C., 1936, sec. IV, Paper No. 12

[4] Handbook on Unitization of Oil Pools, Mid-Continent Oil and Gas Association, Tulsa, Okla., 1930, pp. 15, 16.

[5] Knowlton, D. R., Unitization—Its Progress and Future. Mid-Continent Meeting, Am. Petrol. Inst., Oklahoma City, April 18–19, 1939.

operation changed to scientific unit control as knowledge of the natural forces which promote and retard the underground movement of oil became better known.

Gibson[6] explains the conditions which led to scientific unit control as follows:

"In those countries where petroleum is the property of the State, or where concessions covering large areas are in the hands of single interests, unit control is invariably practiced. In the former category we may instance the Union of Soviet Socialist Republics, and in the latter the best-known examples are the fields of Southwest Iran and Kirkuk field in Iraq. It is indicative also of the importance with which unit control is regarded that in Great Britain, where petroleum has not yet been discovered in commercial quantities, the Petroleum (Production) Act of 1934 contains a clause whereby unit development may be enforced 'in order to secure the maximum ultimate recovery of petroleum and to avoid unnecessary competitive drilling."

(*a*) *The Kirkuk Oil Field.*—The result of scientific unit control in foreign fields is reported by Gross.[7]

"Wells on production: 14. Annual crude recovery: 29,520,680 barrels (80,000 barrels per day). Number of companies' operation: 1. Well-spacing conditions: Minimum 1.4 miles apart; maximum 1.8 miles apart.

"Those look like hypothetical figures of a highly theoretical technologist trying to convince someone 'on paper' of the value of unit operation and planned development of a structure. They aren't. They present a condensed factual picture of the situation today at Kirkuk, a three-dome project operated in Iraq by Iraq Petroleum Co. The domes are on a common structure.

"The years 1933 to 1936 were occupied in drilling enough wells to completely delimit the field and provide wells for observing the changes taking place in the reservoir as a result of the extraction of crude oil.

"During the interval since the last congress, 11 wells have been drilled in Kirkuk area, bringing the total number of wells at the middle of 1937 to 46. The early wells having established the commercial productivity of the field, the wells drilled in 1933–37 period were primarily gas-oil and oil-water observational wells for the purpose of studying the reservoir conditions. The data thus acquired, though in its early stage of use, promise to be a helpful guide to efficient production practice.

"The first oil was dispatched from the Kirkuk field May 21, 1934. The annual and accumulative production figures are as follows (assuming 7.6 barrels to 1 ton):

| Year | Barrels produced annually | Accumulative barrels |
|---|---|---|
| 1934 | 7,091,320 | |
| 1935 | 26,980,760 | 34,073,080 |
| 1936 | 29,520,680 | 63,593,760 |

(*b*) *Comparison, Kirkuk* v. *Yates.*—Comparing these results with the Yates Oil Field, Pecos County, Tex., a field which is pointed to with pride by the petroleum fraternity at large as a model of cooperative operation, we find that in 1938 Yates produced 6,728,426 barrels of oil from 549 wells, or an average of 33.6 barrels per well per day, whereas daily average production per well from the 14 wells on production in the Kirkuk field in 1936 was approximately 5,720 barrels.

The writers do not mean to imply that the daily production of 18,441 barrels from the Yates field could be obtained from 3 wells operating at approximately 5,720 barrels per day because the character of the producing horizons probably differ even though both produce from limestone. Regardless of these differences, however, it is undoubtedly true that the total daily production of 18,446 barrels could have been obtained with one-tenth the number of wells had complete unit operation been in effect.

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[6] Gibson, H. S., B. A., M. Inst. P. T. Scientific Unit Control, The Science of Petroleum, vol. I, p. 535, Oxford Union Press, London, New York, Toronto, 1938.

[7] Gross, Wm. V., Kirkuk Oil Field—Model of Efficient Unit Operation in Near East. Oil Weekly, August 16, 1937, p. 58.

The history of unit operation in foreign fields is further attested by Cadman.[8]

"No well which was producing in Persia in February 1929 has since ceased natural flow on account of declining pressure or of diminished drainage from the reservoir rock.

"The pressure in the gas dome of the Masjid-i-Sulaiman field has only dropped 5 pounds per square inch—approximately 1 percent—during the past 4 years, although a production of nearly 20,000,000 tons has been drawn from the field during that period.

"Perhaps the most useful of the commercial advantages of scientific control is the ability it confers of seeing ahead, of estimating resources, and thereafter of planning how to make the best use of them. Since the production position can be estimated some years ahead, it is now possible to devise a drilling program on economic lines such as were wholly impracticable a few years ago."

(c) *Advantages, foreign over domestic fields.*—The advantages that foreign fields have over domestic fields is shown by Garfias[9] and Whetsel,[9] who say:

"It cannot be overemphasized that as a result of the operation of the 'law of capture,' which controls subsoil ownership in the United States on comparatively small landholdings that seldom if ever cover the entire producing area, the oil fields are not as economically exploited as some foreign fields, and that as a result (were it not for the easy accessibility of the domestic market, the largest in the world) some American production would now be unprofitable in open competition with foreign oils."

## WHAT THE INDUSTRY THINKS OF UNIT OPERATION

### (1) TESTIMONY SUBMITTED TO COMMITTEE IN 1934, H. R. 441 (73D CONG.)

W. T. Holliday, president, Standard Oil Co. of Ohio, Cleveland, Ohio (vol. I, p. 254):

In answer to a question by Congressman Pettengill, Mr. Holliday said:

"If it was done on a unit basis that might offer some better method, because of the more efficient way of producing oil in many fields."

L. V. Nicholas, president, Warner-Quinlan Co., New York, N. Y. (vol. I, p. 534):

"Under the Doherty plan this crazy (law) of capture gives place to a scientific and orderly procedure that gives definite and possessive property rights to each owner's oil as it lies underground and in place, and an orderly production formula gives full protection in each and every owner's interest—and what was formerly a mad scramble to steal the other fellow's oil before he steals yours, is forced to become an orderly, sane, and sensible business transaction."

W. S. Farish, chairman of the board, Standard Oil Co. (New Jersey) (vol. I, p. 672):

"Believing in the manifest advantage of production control from the standpoint either of private gain or public good, the Standard Oil Co. (New Jersey) interests have earnestly supported all serious attempts in this direction. These activities on the part of the company have taken form as follows:

"First, the support of plans for the voluntary unitization of all oil pools in which the New Jersey interests were involved.

"Second, where unit development sentiment did not prevail, as a practical alternative New Jersey interests urged and participated in plans for cooperative development, in which each owner operates in accordance with a common program for the pool.

"Third, in order to enable the industry to attain the objects of unitization and cooperative development of pools and to limit production to demand in times of oversupply, the representatives of the company have advocated modification of the antitrust laws, both State and Federal, to the extent necessary fully to sanction agreements for accomplishing such objects when approved by appropriate governmental authority.

"Fourth, when it developed that voluntary efforts for unitization and cooperative control were not meeting the situation because of minority opposition, the company supported proposals for legislation in which police power of the States would be invoked to secure conservation and production control.

"Fifth, the company supported a proposal by the Federal Oil Conservation Board for a compact among the important oil-producing States for the coordina-

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[8] Cadman, Sir John, Persia, Trans. Am. Inst. Mining and Metallurgical Engineers, Petr. Dev. and Tech., 1933, pp. 399–400.

[9] Garfias, V. R.; Whetsel, R. V.; Estimate of World Oil Reserves; Trans. Am. Inst. Mining and Metallurgical Engineers: Pet. Dev. and Tech. 1939.

tion of control. This was recommended because it became clear that one State could not control its production and effect conservation without similar action on the part of its rivals. The company also subscribed to the restriction of imports in a fair relationship to the restraint imposed on domestic production in the effort to bring supply into balance with demand."

C. B. Ames, chairman of the board, the Texas Co., stated (vol. II, p. 1251):

"An oil pool is a unit, and obviously ought to be operated as such. Diligent efforts are being made to bring about unit operation, and substantial progress is being made. This movement has and is entitled to have the support of the industry. It is so obviously sound that there is practically no division of practicability. Surface ownership does not coincide with the boundaries of the oil deposit, and, therefore, there are numerous surface owners entitled to penetrate the oil sands. Each one desires to recover as much oil as possible, and it cannot be known in advance how much is under the surface of each owner. Some surface owners need the oil in their business, while others do not. Different leases have different drilling operations. The royalty owners are an important part of the picture. This diversification of interest is an obstacle in the way of unit operation. Under the law, a surface owner has the right to drill on his own land. This is a right of which he cannot be absolutely deprived. He cannot be forced into unit operation, and, therefore, unitization must rest upon consent and not compulsion. As the diversity of interest sometimes prevents consent, progress in unitization can only be made gradually and by persuasion."

J. O. Lewis, consulting petroleum engineer, Tulsa, Okla. (vol. II, pp. 1253, 1254):

The following quotations originate from an article by Lewis which appeared in the Handbook on Unitization, published by the Mid-Continent Oil and Gas Association, Tulsa, Okla. Discussing the Cromwell pool, Oklahoma:

"He [Lewis] estimates that unit operation would have increased the recovery of oil one-third over that recovered by competitive operations."

"Lewis estimates an operating profit in the Cromwell pool under competitive operation of $50,600,000. Through (unitization) of the working interests, excluding the royalty interests, the operating profit would have been $102,500,000—a gain of $51,900,000 over actual competitive operation."

Wirt Franklin, president, Independent Petroleum Association of America, and president, Franklin Petroleum Co., Oklahoma City, Okla. (vol. III, p. 1415):

Speaking of unit operation, Mr. Franklin said:

"* * * whenever a majority in acreage and in numbers in a pool of oil agree upon a planned development, there should be machinery provided to make that plan effective and to compel the unruly minority, sometimes only one individual, to comply with that planned development in order to prevent the waste incident to the past methods, to save the gas energy, to prevent the waste of gas, to so withdraw the oil as to get the greatest ultimate recovery, and to prevent excess production in times when there is no demand for it; * * *."

Earl Oliver, Ponca City, Okla. (vol. III, pp. 1577–1580):

The following quotations scarcely begin to express the depth of study and years of effort that Mr. Oliver has given to this subject. Mr. Oliver, probably is one of the best-informed men on unitization of oil pools in the United States. According to Oliver:

"This destruction of an important natural resource and periodic demoralization of a vast industry can be halted only by readjusting oil and gas law until it promotes oil-field-development practices suited to the products handled. To indicate the readjustments that are necessary, it is desirable to summarize the elementary principles, both of oil and gas accumulation and of oil and gas law.

"Because of the nature of oil and gas deposits, it is apparent a national unity of action must be developed in their exploitation.

"Since the Federal Government, the State government, and the property owner each has a distinct and separate function to exercise in this unity of action, it is desirable that a suitable organization be set up for this purpose. I believe all of these functions can be satisfactorily coordinated in some form of organization in which the functions of the Federal Government, of the several States, and of the property owner should be clearly defined."

C. C. Herndon, vice president of the Skelly Oil Co., Tulsa, Okla. (vol. III, p. 1669):

"The only way the law of capture can be perfectly checkmated is through a scheme of absolute unitization of a given oil pool, a merger of titles, so that there becomes one ownership interest. Now, perhaps that cannot be done as a matter of compulsion on the part of the State, but there is something there, I think, that can be done, in all probability, and that is the requirement that oil pools discovered from here on be operated in such a fashion as will reduce the wastage of oil and gas and gas energy, prevent one man from drilling as much as he pleases and operating his well to capacity and dissipating energy, * * *."

Henry M. Dawes, president of the Pure Oil Co., Chicago, Ill. (vol. III, p. 1735):

"From the standpoint of conservation, and every other standpoint, unitization is very effective. It is very difficult to put into effect, but once in effect, I think it is the greatest measure of conservation and economy that could be devised."

J. Edgar Pew, Sun Oil Co. (vol. IV, p. 2033):

"The oil industry is doing its best to help conserve oil. This is in its interest. It has vast investment that can only thus be protected. I am sure I speak for this vast majority of the industry when I recommend, first, that the authority we now have be effectively exercised, and then that—

"1. If possible, the law as to 'capture' be repealed and in its lieu a bottom-hole pressure-acreage basis of recovery be established.

"2. That uniform State laws applying to conservation be passed.

"3. That permissive unitization laws be passed in the various oil States.

"4. That interstate compacts be established."

Mr. Pew's opinion of the desirability of a substitute for the law of capture is shown by the following question and answer:

"Q. It is your judgment, it is, Mr. Pew, that the law of capture is the worst thing that the oil industry has to go up against?

"A. That is correct."

Wallace E. Pratt, vice president, Humble Oil & Refining Co., Houston, Tex. (vol. IV, pp. 2156–2160):

"Uncontrolled production is notoriously and inevitably wasteful production * * *.

"The (Panhandle) is, I think, an example of the waste that comes from uncontrolled production.

"I would operate the field as a unit."

Axtell J. Byles, president of the American Petroleum Institute, New York, N. Y. (vol. IV, p. 2459):

"The industry is not ready to adopt unit operation of pools as such. A great many people are afraid of that yet, but I venture the prediction that in the long run that is the way oil pools will be developed and produced, because of the fact that it is the most efficient way to produce them."

F. E. Heath, petroleum engineer, Sun Oil Co., Dallas, Tex. (vol. IV, p. 2470):

"It is our opinion that the best results can be obtained only by unit operation of the entire pool and that after a reasonable amount of development fairly accurate apportionments can be made to all of the property owners, both lessors and lessees, with reference to giving them their equitable share in the pool, based on the relative amount of oil under each property before any considerable quantity of oil has been produced from the pool."

Calling attention in 1939 to opinions in 1934 of leaders in the industry regarding the benefits that would be derived from unit operation, provided always that such method of production could be put into practical effect, has had two purposes: (*a*) To review briefly for the benefit of the committee members and others the testimony that was presented five years ago; and (*b*) to compare these opinions to more recent expression to determine in what way, if any, these opinions have changed. There follows, therefore, a compilation of more recent expressions on the subject.

### (2) OPINIONS ON UNIT OPERATION SINCE 1934

In his recent address before the tenth annual meeting of the Independent Petroleum Association of America, at Fort Worth, Tex., your chairman, Congressman Cole, indicated the desire for more recent information regarding the success of unit operation projects put into effect since 1934. Chairman Cole's statement was:

"Four years have passed since the Congress authorized the Secretary of the Interior to require the submission of unit plans when public lands were to be leased for the production of oil and gas. Sufficient time may now have elapsed to permit of some valuation of the merits of these plans and whether they are effective in promoting an increased recovery of oil."

The writers will not attempt to reply to Congressman Cole's specific reference to the success of unitization projects on public lands, as they are informed that other statements by representatives of the United States Geological Survey will cover the subject thoroughly from that standpoint. With respect to the success of other unit operations, reference is made to Salnikov's remarks on page 40 regarding the South Burbank pool, Oklahoma.

In neither the 1934 committee report under H. R. 441, nor in more recent expressions have the writers been able to find that the two large associations that represent the petroleum industry, the Independent Petroleum Association of American and the American Petroleum Institute, have ever gone officially on record as favoring unit operation as such. Both associations, however, have gone on record in numerous instances as favoring the results relating to conservation and efficiency that their leaders believe could be accomplished by unit operation.

*Independent Petroleum Association of America, committee report.*—Five years ago, Wirt Franklin, president of the Independent Petroleum Association of America went so far as to say that he personally would favor compulsory unit operation whenever a majority in acreage and in acreage and in numbers had agreed upon planned development. That the idea of unit operation may be making progress in the Independent Petroleum Association of America as a group is indicated by committee report[10] on Unnecessary and Unprofitable Drilling. Included in this report is the following statement:

"It should also be pointed out that the growing tendency of operators to unitize small tracts into drilling units, and even to unitize their properties into large operating units, is becoming more prevalent than in the past. This practice results in the greater saving in development costs.

"Although substantial progress is being made toward eliminting unnecessary wells, it is still one of the main causes for our economic ills in the industry. Operators continue to drill unnecessary wells in large numbers, and the allowable per well is being continually reduced to a level which results in a longer and longer pay-out for capital invested."

In June 1936, Axtell J. Byles, president of the American Petroleum Institute stated:[11]

"Development and operating costs can be reduced and full production obtained by wider spacing of wells and more cooperative development programs, and, where possible, by unit operations."

Frank Phillips, chairman, Phillips Petroleum Co.: Mr. Phillips is one of the leading exponents of unit operation in the oil industry. His recent article "Streamlined Science Needs Horse-Sense Economics"[12] praises the value of unitization.

Mr. Phillips cites the following advantages of unit operation:

"In general, fewer wells are needed; there is maximum economy of operation; reservoir control is made practical; individual risk is minimized; a stabilizing effect is imposed on the market; an investment results that is more salable and on which loans can be readily obtained; it increases per-acre yield of oil; an increased value is created for the gas; it permits adjustment of production rate to the producer's needs; it effects savings on pipe lines, storage tanks, and plant capacity, and makes possible the practices of pressure maintenance, repressuring, recycling, and water flooding."

Mr. Phillips also stated that—

"Uuit operation should have a special appeal to every small operator, for it provides the only channel through which he can share in improved methods of operation, otherwise available only to big operators who may control entire pools and compete in the same markets. The small operator certainly should be 'Unit Conscious.'"

Mr. Phillip's statement in the November 25, 1939, issue of the National Petroleum News regarding the Cole bill does not contain any change in his views on unitization of oil pools.

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[10] Report of the Subcommittee on Unnecessary and Unprofitable Drillin. Presented at the tenth annual meeting of the Independent Petroleum Association of America, Fort Worth, Tex., October 18, 1939.

[11] Production and the Compact, an address delivered by President Axtell J. Byles, of the American Petroleum Institute, before the annual meeting of the eastern district of the Institute's Division of Production in the William Penn Hotel at Pittsburgh, Pa., June 4, 1936.

[12] Phillips, Frank. The Mines Magazine, June 1939, Denver, Colo., p. 25.

Testimony given recently before the Temporary National Economic Committee revealed divergent views on unit operation.

Dr. Joseph E. Pogue, vice president, Chase National Bank, New York: In his analysis of conservation and proration before the Temporary National Economic Committee, Dr. Pogue is reported to have stated[13] that the procedure of unit operation is gradually gaining headway in the business and that the formation of pool cooperatives should certainly be encouraged in every feasible manner, but the progression toward full unitization, while persistent, is slow, because of the principle of deferment.

Herman Stabler, chief of the conservation branch of the Geological Survey: Mr. Stabler testified before the Temporary National Economic Committee that 112 unit plans on public oil lands had been accepted. These plans cover an area of 1,639,593 acres.

John E. Shatford and Karl A. Crowley: Criticism of unitization was made by John E. Shatford of El Dorado, Ark., and Karl A. Crowley, of Fort Worth, Tex., at the Temporary National Economic Committee hearings from the standpoint of stifling the operator owning small tracts of land and harassment by large operators. These men, however, offered no criticism of unit operation from the standpoint of efficiency and conservation.

*Works Projects Administration in cooperation with the United States Bureau of Mines.*—The publication Technology, Employment, and Output Per Man in Petroleum and Natural-Gas Production, July 1939, prepared by the Works Projects Administration, National Research Project, on page 157, gives this statement regarding unit operation:

"Unit operation the technical ideal: The need for conserving and harnessing the powerful natural forces in an oil or gas reservoir if maximum recovery is to be obtained suggests the desirability of exploiting that reservoir as a single gigantic engineering project. The primary object of such technical control is to obtain the maximum recovery of oil at the lowest possible cost. Production with these objectives is most frequently identified in the industry by unit operation, a term that is loosely used to describe both adequate technical control over an entire reservoir and legal or economic arrangements whereby the interests of different property owners are reconciled to permit unified technical control. Such operation is the antithesis of production under the rule of capture whereby each operator or landowner endeavors to procure all the oil possible from wells on his property without any regard as to how much of the pool's potential productivity may be lost because of destructive individualistic productive practices; it also is potentially more efficient than production under the usual proration programs. Sponsorship of unit operation as a technical ideal is not new, but there have been serious barriers to its more widespread adoption."

*Natural Resources Committee.*—The report of the Energy Resources Committee in January 1939 on Energy Resources and National Policy to the National Resources Committee makes the following statement on unit operation on page 2:

"In many States the courts have already modified the rule of capture so that a landowner can recover only a certain amount of oil within a given period. Although the right of capture has been modified somewhat, it needs to be completely displaced by a thoroughgoing law of ownership in place, which would allot to each producer that proportion of the oil and gas in the common reservoir which underlies the land he owns or controls. The economic advantages of unit operation and scientific management of oil and gas pools are so overwhelming and so generally approved by technicians that some legal advice of providing for their adoption and enforcement will surely be forthcoming as the threat of exhaustion becomes imminent."

## New Problems Relating to Unitization

### (1) SECONDARY RECOVERY PLAN FOR THE OKLAHOMA CITY POOL

To suggest unitization of the Oklahoma City pool 10 years after discovery and after a yield of approximately 450,000,000 barrels might appear to be a case of locking the barn door after the horse has been stolen. Nevertheless, engineers have given much thought to the subject and believe that there still remains in this field some 300,000,000 barrels of oil, a large portion of which can be recovered by the application of advanced secondary recovery methods. These expressions of opinion are invariably accompanied with the stock-worn

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[13] The Oil and Gas Journal, Tulsa, Okla., September 28, 1939, p. 18.

proviso regarding a satisfactory unit operating agreement. According to the writers' information, the principle of recovery would be to create up-structure water flooding and down-structure gas propulsion, possibly augmented by localized gas drives. Capable engineers consider the technical features of the plan to be feasible, but fear that "hold outs" who insist upon their constitutional rights may defeat the project.

### (2) SECONDARY RECOVERY PLANS FOR SALT CREEK POOL, WYOMING

The recent culmination of plans for the unitization of the Salt Creek field in Natrona County, Wyo., the largest field discovered in the northern Rocky Mountain area, marks a new epoch in the history of unitization, as it is a rare incident for a fully developed field the size of Salt Creek to be unitized.[14]

Unit operations for secondary recovery in this field began on September 1, 1939. Only a few small tracts around the outer rim are not unitized. Better than 90 percent of all owners of leases, working interests, and royalties, including Federal and State land, have been brought into agreement.

Midwest Oil Co. and Mountain Producers Corporation jointly are operators for the unit and have employed Standolind Oil & Gas Co. to do the field work under a long-time contract. The field has been fully drilled up, with approximately 1,300 wells on production from the several sands. Production from the unit wells at present is approximately 12,000 barrels a day. Typical wells in the field run from 10 to 15 barrels per day, the range actually being from 1 barrel to 80–100 barrels, with comparatively few within the last-named category. Strictly speaking, it is a stripper field, with nearly all of the wells being pumped.

Engineers began working on the plan about 4 years ago and made studies in the determination of ratios applicable to the different tracts in the field in proportion to the ultimate recovery from the unit as a whole. No attempt was made to estimate the quantity of recoverable oil in barrels for the entire field nor to determine ratios on the basis of acreage or productivity, but to set up equitable ratios which will apply regardless whether future production amounts to 50.000,000 or 100,000.000 barrels. This was made possible because there are no unknown elements as to the participation, the field being fully developed.

The principal objective of the unit will be to slow down the rate of decline of production by the introduction of the most modern and approved methods and for the more economical operation of the field from a single central plant. The unit hopes to undertake some effective clean-up work by a more extensive application of the gas drive and other measures of secondary recovery.

Up to January 1, 1939, the field has produced approximately 283,000,000 barrels. Engineers have estimated this amount represents about 22 percent of the maximum recovery. If, over a period of several years, the gas pressure can be increased to 500 to 700 pounds, it is estimated another 215,000,000 barrels can be recovered, especially if the pressure then be raised up to 1,000 pounds.

### (3) CONDENSATE POOLS

Since the hearings of 1934 under H. R. 441, a new type of pool has received recognition. In condensate pools the area of the gas cap is frequently large in comparison to the area of oil-bearing portion, and the pools necessarily have a high reservoir pressure, and, therefore, are deep seated.

Although "condensate" or "distillate" wells such as existed at Kettleman Hills, Calif., Oklahoma City, Okla., Moore, Okla., Turner Valley, Canada, and other places have been known for many years, it is only within the past 2 years that the true characteristics and significances of the reservoir conditions which created these "freak" wells have been generally understood.

The usually accepted theory is that the gas cap of condensate pools contains in the gaseous phase a much larger proportion of the heavier hydrocarbons than are usually contained in the gas caps of fields under low pressure. In nontechnical language this means that the gas in the gas cap contains a large portion of vaporized gasoline, which in shallower fields instead of being a component of the gas would be a component of the oil.

Formerly, in the operation of condensate wells, the gasoline vapors condensed (retrograde condensation) upon reduction of pressure in the flow string and in the oil-gas separator at the surface. Frequently the liquid was sold from tankage

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[14] The Oil and Gas Journal, August 31, 1939, p. 14.

at the well to tank wagons or trucks. If no market existed for the gas, it was blown in the air. It was not uncommon to use this liquid directly in automobiles without refining.

The experience of these operations showed that after considerable gas had been withdrawn from the reservoir with resultant reservoir pressure reduction, the liquid or condensate production became less and less, and finally ceased entirely. In several instances in the Gulf coast area the lower limit of this pressure was approximately 1,500 pounds per square inch.

With our present knowledge we now know that when the condensation diminished in the flow string and gas-oil separator that it was taking place on the surface of the sand grains in the reservoir. Such condensation, if it could be seen, would have the appearance of the thin film of moisture that appears when one's breath is blown again a cold window pane. Obviously a large portion of the gasoline remaining in the reservoir under such conditions would be unrecoverable—lost.

The prevention of such loss is now accomplished by so-called recycling operations wherein the pressure is maintained on a reservoir by returning gas denuded of its gasoline vapors to the upper part of the structure by means of high-pressure compressors. The denuded gas displaces the original reservoir gas, and gas in its original state is continually withdrawn from the lower portion of the structure. There is little danger of admixture of denuded gas with the original gas containing gasoline vapors, provided the denuded gas is returned to the upper part of the structure.

Naturally the successful operation of this plan depends entirely upon cooperation between the leaseholds on top of the structure with those on the flanks. By such cooperation the pressure above the retrograde condensation range will be maintained.

Voluntary cooperative arrangements for these operations are not beset with the difficulties met when unitization of ordinary oil pools is attempted. The probable reasons are (*a*) that there is little or no market for the gas in the regions where condensate pools are being discovered and (*b*) operations by the blowing of gas to the air would probably be stopped after complaint to the regulatory bodies by offset operators; (*c*) small leasehold interests could hardly afford the expense of installing separate recycling plants; (*d*) the owner of a small tract would be beset with the expense of at least two wells, one for input and one for withdrawal; (*e*) such operation would soon be unsuccessful because of admixture of the denuded gas with the original gas.

Because of the conditions described, unitization projects such as the one recently consummated in the east Alice field, Texas., have not met with the difficulties frequently encountered in similar projects relating to oil production. The character and size of the east Alice project is indicated by the following excerpt:[15]

"Corpus Christi: The long-expected recycling and natural gasoline project for the east Alice field of Jim Wells County has been announced. Davis & Co., of New York and Houston, is completing a deal with leaseholders to unitize 1,672.5 acres for the construction of a $500,000 plant. Work is to commence within a few weeks.

"A total of 1,672.5 acres has been unitized. These leases are owned by Tom G. Graham, H. J. Mosser, W. B. Osborn, Mrs. R. B. Bryant, H. H. Howell, Henshaw Bros., Stroube & Stroube, Al Buchanan Production Co., W. H. Matthews, and Earl Callaway."

Under other conditions, such as a ready market for some of the gas, it is questionable if voluntary unitization would prove successful.

The most recent article published on the subject of unitized condensate pools is the Case of Unitization in Recycling by George Weber in the Oil and Gas Journal, November 9, 1939, page 39.

### (4) THE FOREST CITY BASIN

The potential problems presented by the active prospecting in northwest Missouri, northeast Kansas, southeast Nebraska, and southwest Iowa do not pertain strictly to the subdivision New Problems Relating to Unitization. Actually they are old problems in a new location.

Although the hazard to the oil industry presented by the intense leasing and wildcatting activity covering the described area cannot be considered great until some of the operations are successful, nevertheless the unparalleled activity over

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[15] East Alice recycling plant details arranged. Oil Weekly, August 7, 1939, p. 60.

such an extensive area wherein hundreds of thousands of acres have been leased in four States, three of which have no oil-conservation laws, presents an opportunity to consider the effect upon the petroleum industry if a large field should be discovered which extended over portions of two or more of the States.

This possibility became slightly more real when, on November 2, 1939, a news item in a Washington paper[16] reported the discovery of a well at a depth of less than 3,000 feet, estimated to have a minimum capacity of 50 barrels per day. The writers have seen no confirmation of this report and are not attempting to visualize an East Texas, a Seminole, nor a Spindletop, but it occurs to them that hazards of this nature exist today as they always have existed, and common sense dictates that ways should be devised to convert into a national asset the catastrophe of discovering a possible 100,000,000 barrel oil reserve.

(*a*) *Provision in lease form, giving right to unitize.*—The relation of these remarks to unit operation and unitization of oil pools lies in the fact that nearly every one who has given thought to the problems of unitization admits that such plans can best be made before the discovery of oil. Still, so far as the writers are aware, nothing has been done in this tremendous leasing campaign which would assist in unitizing the leased areas. It would have been simple to have inserted a clause in the standard lease form wherein the lessor agrees to accept his percentage royalty from the amount that the leasehold interest might receive from any unit agreement that may be entered into. In support of this idea, Glassmire[17] says:

"A provision is inserted in certain lease forms giving operators the right to unitize the lease, but the privilege has been jealously guarded by landowners."

Following is the provision suggested by Glassmire:[17]

"If lessee at any time shall agree with other lessees or landowners to develop and operate the several leases or tracts covered by such agreement as a single property, or in accordance with drilling and operating methods common to the several leases or tracts embraced in such agreement, lessee shall have the right to include lessor's royalty interest in said agreement, and, thereupon, in respect of the number of wells to be drilled on the land covered hereby, the location thereof, the time of drilling same, the rate of production therefrom, and such other drilling and operating methods as may be prescribed in said agreement, the terms of said agreement exclusively shall control, any provision or provisions of this lease to the contrary notwithstanding. If said agreement shall provide for the development and operation of the leases and tracts included therein as a single property, and if said leases or tracts, or any of them, shall produce oil in paying quantities, then such part of quantity of said production as shall be allocated to this lease under said agreement shall be divided as follows, seven-eighths to lessee and one-eighth to lessor. Provided, in respect of gas production developed under said agreement, whether from oil wells or from wells producing gas only, lessor shall receive such proportion of the gas royalties stipulated herein as the acreage of this lease bears to the entire acreage covered by said agreement. Should production in paying quantities be found on any of the leases or tracts covered by said agreement, this lease shall remain in force as long as such production continues. If this lease shall be unitized with other leases or tracts, and if production shall be found on any of them, lessee's rental obligations hereunder shall cease when lessor's royalties payable under this paragraph shall equal or exceed the annual rental. Any agreement made by lessee under this paragraph shall be in writing and lessee shall furnish lessor with a photostat of the signed agreement."

(*b*) "*Community oil and gas lease.*—

"Oil and Gas Lease

(Community ——)

"The Kansas Blue Print Co.

"This agreement, made and entered into this ____ day of __________, 193__, by and between ____________________________________________________

________________________________________________________________________

of ______________, party of the first part, hereinafter called lessor (whether one or more), and ______________, party of the second part, lessee:

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[16] Also see Oil Weekly, November 6, 1939, p. 55.

[17] Glassmire, S. H., Oil and Gas Leases and Royalties, second edition, Thomas Law Book Co., St. Louis, 1938. P. 39, pp. 402–403.

"Witnesseth: That the lessor for and in consideration of ------------------- dollars, in hand paid, receipt of which is hereby acknowledged, and of the covenants and agreements hereinafter contained on the part of the lessee to be paid, kept and performed, has granted, demised, leased, and let, and by these presents does grant, demise, lease, and let unto said lessee, with the exclusive right to prospect, explore, by use of core drills or otherwise, to mine, operate, produce, store, and remove therefrom oil, gas, casinghead gas, and all petroleum products; and to build tanks, powerhouses, such other houses necessary for convenience of employees, stations, and structures thereon to produce, save and take care of and manufacture all of such substances, together with the rights-of-way, easements, and servitude for pipe lines, telephones, and telegraph lines, with the right for such purposes to the free use of oil, gas, or water from said land, but not from the lessor's water wells or ponds, with the right of removing, either during or after the term hereof, all and any improvements placed or erected on the premises by the lessee, including the right to pull all casing, all that certain tract of land situated in the county of ----------, State of --------------, described as follows, to wit: ------------------------

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of section ------------, township -------------, range --------------, and containing -------------- acres, more or less.

"To have and to hold the same for a term of 10 years from this date, and as long thereafter as oil or gas or casinghead gas, or any of them, is produced therefrom, or as much longer thereafter as the lessee in good faith shall conduct drilling operations thereon, and should production result from such operations, this lease shall remain in full force and effect as long as oil and gas or casinghead gas shall be produced therefrom.

"In consideration of the premises, it is hereby mutually agreed as follows:

"1. Lessee shall deliver to the credit of the lessor, as royalty, free of cost, in the pipe line to which it may connect its wells, the equal one-eighth (⅛) part of all oil produced and saved from the leased premises, or at the lessee's option to pay lessor for such royalty at the posted market price prevailing in the midcontinent field for oil of like gravity the day the oil is run into the pipe line or storage tanks, and in this last event, settlement shall be made by the lessee on or before the 15th day of each month for the accrued royalty for the preceding calendar month.

"2. The lessee shall pay lessor, as royalty, one-eighth (⅛) of the market value in the field for gas from each well where gas only is found while the same is being sold or used off the premises, and shall pay to the lessor the sum of fifty dollars ($50) each year as royalty on each gas well where gas only is found and same is not used or sold, and while said royalty is so paid said well shall be held to be a producing well under the habendum clause of this lease. The lessor to have gas free of charge from any gas well on the leased premises for all stoves and inside lights in the principal dwelling house on said land by making his own connections with the well, the use of said gas to be at the lessor's sole risk and expense at all times.

"3. The lessee shall pay to lessor for gas produced from any oil well and used by the lessee for the manufacture of gasoline, as royalty, one-eighth (⅛) of the market value at mouth of well of such gas. If said gas is sold by the lessee, the lessor shall receive as royalty one-eighth (⅛) of the market value in the field of such gas.

"If operations for the drilling of a well for oil or gas are not commenced on said land on or before 1 year from this date, this lease shall terminate as to both parties, unless the lessee shall, on or before 1 year from this date, pay or tender to the lessor or for the lessor's credit in the ------------- Bank at -------------, or its successors, which bank and its successors are the lessor's agent and shall continue as the depository of any and all sums payable under this lease, regardless of changes of ownership in said land or in the oil and gas, or in the rentals to accrue thereunder, the sum of one ($1) dollar per acre which shall operate as rental and cover the privilege of deferring the commencement of drilling operations for a period of 1 year. In like manner and upon like payments or tenders, the commencement of drilling operations may be further deferred for like periods successively, during the original term of this lease as fixed in the habendum clause hereof. All payments or tenders may be made by check or draft of lessee or any assignee thereof, mailed or delivered on or before the rental paying date.

"Notwithstanding the death of the lessor, or his successor in interest, the payment or tenders of rentals in the manner provided above shall be binding on the heirs, devisees, executors, and administrators of such persons.

"If at any time prior to the discovery of oil or gas on this land and during the term of this lease, the lessee shall drill a dry hole, or holes, on this land, this lease shall not terminate, provided operations for the drilling of a well shall be commenced by the next ensuing rental-paying date, or provided the lessee begins or resumes the payment of rentals in the manner and amount above herein specified; and in this event the preceding paragraphs hereof governing the payment of rentals and the manner and effect hereof shall continue in force.

"When required by lessor, the lessee shall bury pipe lines below plow depth and shall pay for damage by its operations to growing crops on said land.

"If the estate of either party is assigned (and the privilege of assigning in whole or in part is expressly allowed), the covenants hereof shall extend to their heirs, executors, administrators, successors, and assigns, but no change of ownership in the land or in the rentals or royalties shall be binding on the lessee until after notice to the lessee and it has been furnished with the written transfer or assignment or certified copy thereof.

"It is further stipulated, accepted, agreed to, and made an express condition of this contract of lease that several lessors whose signatures are hereunto affixed, by executing this lease, intend to and do hereby pool or put together in one joint enterprise all the tracts of land covered and affected hereby, which tracts of land are designated herein as the leased premises, and to that end it is agreed that said leased premises shall be by the lessee or its successors in interest in all and every respect (including the drilling of wells originally and with regard to offsets, operation of the property, payment of rentals and royalties, gaging and measuring of the oil or gas produced and in all other respects) considered, developed, and operated as one single property or one tract, i. e., as one lease, and all rentals and royalties or other benefits accruing hereunder shall be treated and paid as an entirety and shall be paid to and divided among the several separate owners in the proportion that the acreage owned by each of such separate owners bears to the whole of said "leased premises," and there shall be no obligation on the part of the lessee to offset wells on separate tracts into which said "leased premises" may already be or hereafter be divided by present ownership, or by sale, devise, or otherwise, nor shall lessee be obligated to furnish separate measuring tanks or receiving tanks or other devices of gaging or measurement; the several lessors expressly hereby acknowledging that to require lessee to develop and operate the several tracts of land comprised within said "leased premises" other than as one single tract or lease would be entirely impractical for the reason that said several tracts of land are of small area, ranging from less than one acre to larger tracts, the same being lots, plots, and tracts in or near the town of ______________, State of ______________.

"It is hereby agreed that, in the event this lease shall be assigned as to a part or as to parts of the above-described lands, and the holder or owner of any such part or parts shall fail or make default in the payment of the proportionate part of the rent due from him or them, such default shall not operate to defeat or affect this lease insofar as it covers a part or parts of said land upon which the said lessee or any assignee hereof shall make due payment of said rentals.

"If at any time there be as many as six parties (or more) entitled to receive royalties under this lease, lessee may withhold payment hereof unless and until all parties designate in writing in a recordable instrument to be filed with the lessee, a trustee to receive all royalty payments due hereunder and to execute division and transfer orders on behalf of said parties and their respective successors in title.

"Lessor hereby warrants and agrees to defend the title to the land herein described and agrees that the lessee, at its option, may pay and discharge any taxes, mortgages, or other liens existing, levied, or assessed on or against the above-described lands, and, in event it exercises such option, it shall be subrogated to the rights of any holder or holders thereof and may reimburse itself by applying to the discharge of any such mortgage, tax, or other lien, any royalty or rentals accruing hereunder.

"Notwithstanding anything in this lease contained to the contrary, it is expressly agreed that if lessee shall commence drilling operations at any time while this lease is in force, this lease shall remain in force and its term shall continue so long as such operations are prosecuted and if production results therefrom, then so long as such production continues.

"If within the primary term of this lease production on the leased premises shall cease from any cause, this lease shall not terminate provided operations for the drilling of a well shall be commenced before or on the next ensuing rental-paying date; or, provided lessee begins or resumes the payment of rentals in the manner and amount hereinbefore provided. If, after the expiration of the primary term of this lease, production on the leased premises shall cease from any cause, this lease shall not terminate provided lessee resumes operations for drilling a well within sixty (60) days from such cessation, and this lease shall remain in force during the prosecution of such operations and, if production results therefrom, then as long as production continues.

"It is agreed that this lease shall never be forfeited or canceled for failure to perform in whole or in part any of its implied covenants, conditions, or stipulations until it shall have first been finally judicially determined that such failure exists, and after such final determination, lessee is given a reasonable time therefrom to comply with any such covenants, conditions, or stipulations.

"All rental payments which may fall due under this lease may be made to __ __________, one of the above-named lessors, in the manner herein stated.

"This lease and all its terms, conditions, and stipulations shall extend to and be binding on all successors of said lessor or lessee.

"In testimony whereof, we sign this instrument the day and year first above written."

### (5) ABILITY OF ENGINEERS TO DETERMINE THE "EXTRACTABLE ACREAGE CONTENT" OF A POOL

"To the question as to whether engineers can determine extractable acreage content within the standard set by lawyers, not with mathematical accuracy, but with reasonable justice to oil concerned, * * *" Oliver[18] summarized the replies received from 16 engineers as follows:

"From the foregoing expressions it is clear that engineers believe that methods can be devised whereby the relative content of adjacent tracts in a common pool can be determined with justice to all concerned. Up to this time there has been no great need for developing accurate technique on this problem, but if that becomes a regular procedure in oil-field development, engineers will soon evolve methods for determining these facts with a great degree of reliability and sufficiently close to do substantial justice to all. As better methods are found from time to time they can and will be applied."

The above expression represents the thought of engineers in 1932. Since then, the task of estimating extractable acreage content has been greatly aided by the development and use of electrical logging methods for determining the character of the formations penetrated, and also by improved coring devices, wherein samples of the producing formations may be brought to the surface for inspection and laboratory examination. Both electrical logging and coring are still in the revolutionary starge. Without doubt, valuable as they are, still greater dependence will be placed upon them in the future.

Confusion regarding the ability of engineers to estimate reserves with "reasonable accuracy" undoubtedly has been devolped in the minds of laymen from careless statements and ignorant criticisms regarding discrepancies such as relate, for example, to the estimated reserves of the east Texas field.

The first authoritative estimate that the writers recall was 1,500,000,000 barrels. This estimate was raised later to approximately 4,000,000,000 barrels.

The first estimate was based upon the limited data available at the time it was made. The higher estimate made several years after was based upon more complete data. In neither instance, however, did the data originate for the specific purpose of estimating reserves. Another cause for confusion relates to the difficulty of estimating recoverable oil from specified tracts within a field. Nearly all engineers agree that it is less difficult to estimate reserves of an entire pool, provided sufficient data are obtained, than to estimate the amount of oil that might be recovered from a particular tract. The gain or loss through offset drainage between tracts is the unknown factor.

The problem in unit operation of equitable apportionment among tracts, however, is not a problem of how much oil a tract might produce through wells drilled upon that tract, but what portion a tract would contribute to the pool total. This is a much less difficult approach and has the advantage of meeting with the more advanced legal concept of property rights as stated by the Supreme Court of Texas in *Brown* v. *Humble Oil & Refining Co.:*[19]

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[18] Earl Oliver, Stabilizing Influences for the Petroleum Industry. Trans. Am. Inst. Min. & Met. Engineers, Pet. Dev. & Tech., 1932, pp. 31–37.

[19] (Tex. 1935) 83 S. W. (2d) 935, at p. 944.

(*a*) *The Brown* v. *Humble Decision.*—The court's statement:

"Also, conditions may arise where it would be proper, right, and just to permit tracts to be subdivided and such subdivisions drilled after the adoption of the rule;[20] but in all such instances it is the duty of the commission to adjust the allowable, based upon the potential production, so as to give to the owner of such smaller tract only his just proportion of the oil and gas. By this method each person will be entitled to recover a quantity of oil and gas substantially equivalent in amount to the recoverable oil and gas under his land. * * *"

## Progress in Unitization Since Committee's Report of 1934

### (1) OUTSTANDING EXAMPLES OF UNITIZATION

A number of pools have been unitized since the 1934 report of the Special Subcommittee on Petroleum Investigation.

In Oklahoma, the South Burbank unit,[21] Ramsey unit,[21] Billings unit,[21] North Avant unit,[21] and Naval Reserve unit[21] are the most noteworthy.

Several of the most publicized unitized projects in other States are: Tepetate in Louisiana, Lance Creek and Salt Creek in Wyoming, the Van Pool in Texas, and the Stumps,[21] Prusa,[21] Schroeder,[21] Morel,[21] Graber, Cramm,[21] Edwards,[21] Haferman,[21] Plogg, Soeken,[21] Leesburg,[21] Rattlesnake,[21] Zenith,[21] Burkett, Demalorie-Sowder, Scott, and Teeter Pools in Kansas have have partially unitized. Centrahoma, Burbank, Moore, Britton, Lamont,[21] Lucien, North Lucien, Polo, Fox-Deep Sand, Milroy, Stillwater, Gray, Bethel, North Bethel,[21] North Earlsboro,[21] Keokuk Falls, Sasakwa Townsite, Searight, North Searight, Seminole City in Oklamoma are other examples of pools unitized in part.

Probably the most publicized pool in Oklahoma being operated under a unitized plan is the South Burbank oil field of Osage County.

Recent information regarding the success of this plan appears on the oil page of the Wichita Beacon of Wichita, Kans., of July 6, 1939.

According to Ivan S. Salnikov, chief engineer of the Carter Oil Co., Tulsa, Okla., an ultimate recovery of as high as 15,000 barrels of oil per acre can reasonably be expected from the unitized development in the South Burbank field developed entirely on 20-acre spacing. This represents an estimated increase of 5,500 barrels per acre over that of the old Burbank pool where the maximum recovery was only 9,500 barrels per acre and developed on 10-acre spacing, wide-open flow, and without repressuring. Computed on the 2,300 acres in the South Burbank unitized block, this would represent an additional recovery of approximately 11,600,000 barrels before the properties are completely exhausted. The South Burbank block has aleady produced 7,000 barrels to the acre, representing an accumulated production to date of about 15,000,000 barrels.

Salnikov also pointed out the advantage of pressure maintenance in prolonging the flowing life of an oil field, citing the fact that the old Burbank field yielded only 4,000 barrels per acre of flowing production under wide-open flow method with no secondary recovery, while the South Burbank pool already has produced more than 7,000 barrels of oil per acre through pressure maintenance and other methods with all 200 wells still flowing, an increase of approximately 7,000,000 barrels of additional oil obtained in the flowing stage. More than 15 billion cubic feet of natural gas has been injected into the South Burbank reservoir to date in the unitized area through eight input wells situated on the east side.

Salnikov stated that the original bottom-hole pressure was 910 pounds with the present bottom-hole pressure of about 500 pounds. Withdrawals bring about only an 8-pound reduction in pressure per month.

During the past few years a tendency toward unitization of technical effort has stimulated the growth of field cooperative engineering committees such as the East Texas Engineering Committee, Yates Pool Engineering Committee, Goldsmith Pool Engineering Committee, North Basin Pools Engineering Committee, Conroe Operators Association, Oklahoma City Wilcox Secondary Recovery Association, and others. In western Kansas, company petroleum engineers organized a cooperative group titled "The Kansas Society of Petroleum Engineers"

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[20] The court refers to rule 37 which provides for 10-acre spacing.

[21] Pools unitized since 1934 (in whole or in part).

which meets monthly to discuss common engineering problems and to exchange ideas.

These committees usually record and analyze data and make recommendations for efficient operating practices. Their growth signifies the necessity of operating oil pools as units. Their success has been commendable, but they cannot hope to even approach the results that would be obtained through complete scientific unit control.

### (2) SALT-WATER DISPOSAL

Unitization efforts have fostered the growth of community salt-water-disposal systems whereby the salt water produced with oil is injected into subsurface formations other than fresh-water-bearing strata. The contamination of surface streams and other sources of domestic water supply is thereby avoided.

In several fields, operators have formed brine-disposal companies to take care of the drainage from well locations and tank batteries on oil-producing properties.

In coastal oil fields, waste-water-disposal companies have been in operation for several years. The problem there is the separation of the oil from the brine and subsequent disposal of the waste petroleum; the brine is disposed of easily in nearby bodies of salt water.

The Bureau of Mines report of investigation No. 3394, titled "Disposal of Petroleum Wastes on Oil-Producing Properties," describes the cooperative water-disposal company owned by the operators in the Santa Fe Springs, Whittier, Montebello, and Rideout Heights oil fields in California. The initial cost of the plant and pipe lines was approximately $507,000. In 1936, the quantity of waste water handled by the company was approximately 72,000 barrels a day.

The Transwestern-Mezger Raymond Pool cooperative brine-disposal system in Kansas is described in detail in the Bureau of Mines report of investigation No. 3434, titled "Typical Oil-Field Brine-Conditioning Systems: Preparing Brine for Subsurface Injection."

In Oklahoma the 1938–39 report of the Pollution Department of the Division of Water Resources of the Oklahoma Planning and Resources Board describes the Edmond Pool cooperative salt-water-disposal system which is owned by five companies and operated by the Ohio Oil Co.

In the Fitts Pool, in Oklahoma, 11 companies are included in the Fitts Salt-Water Association, which spent $275,000 on a salt-water disposal system described in the December 1938 issue of the Petroleum Engineer magazine.

In the East Texas field the problem of salt-water disposal is serious as indicated in the article "East Texas as It is Today" by George Weber in the April 27, 1939, issue of the Oil and Gas Journal.

This article states: "The problem of disposing of salt water without danger of stream pollution is reaching a critical stage. The establishment of large-scale disposal systems such as are found in other fields has been delayed in east Texas largely because most of the operators in the present water-producing zone are independents who produce relatively small leases and cannot economically justify the expense of undertaking new and costly experiments on returning salt water to underground sands * * * the cost of salt-water disposal may figure largely in the economics of well abandonment within the next few years in east Texas."

Utilization of fields offers an ideal solution to the problem of salt-water disposal in that duplication of facilities for disposal can be avoided and would enable the small independent operator to bear his expense in proportion to the large operator who is generally more able to pay his way. Premature abandonment of wells can be prevented by unified effort to combat the salt-water problem.

More attention is being directed to the conservation of our fresh-water resources which have been polluted severely in several of our oil-producing States.

The State of Kansas has the best legislation on salt-water disposal of any State, and much credit is due the Kansas State Board of Health and the Kansas State Corporation Commission in their effort to assist the oil industry in attempting to solve the salt-water pollution problem.

## SUMMARY AND CONCLUSIONS

(*a*) *Percentage of unit operated pools to total.*—Mr. Frank Phillips[22] stated in his paper "Streamlined Science Needs Horse-Sense Economics" that there are now some 185 pools operating under one form or other of unit procedure.

Although the efforts toward more efficient methods of producing oil through unit operation are highly commendable, the fact remains that the actual number of pools so operated is small compared to the more than 3,000 pools in the United States which are either producing or amenable to secondary recovery operations. Furthermore, it can be safely assumed that only a small portion of the 185 pools reported by Phillips[21] are 100 percent unitized as to both fee and leasehold interests. The writers know of no pool that can be placed in this category although the Sugarland Field in Texas might so be placed.

(*b*) *One-hundred percent unitization the ideal.*—All of the fee and leasehold interests should become parties to a unitization agreement if the greatest benefit from scientific unit control is to be obtained. A step in this direction would be the general adoption of a standard lease form to include a supplementary clause similar to the one suggested by Glassmire[23] on page 29.

Such clause would require the fee interests to become part of any general plan of unitization that the leasehold interests might enter into.

Kansas Oil and Gas Lease "community" is specimen of this type of lease.

(*c*) *Less than 100 percent unitization presents difficulties.*—The failure of the Kettleman Hills, Calif., unit and cooperative agreements to result in "scientific unit control" has been brought about largely through the operating policies of minority interests controlling not more than 3.3 percent of the total acreage. The facts supporting this statement were disclosed completely at a hearing by the Petroleum Administrative Board in December 1934.[24] A comprehensive account of this failure and its causes also are fully reported by Miller and Shea[25] in the present hearings of this committee.

Because of this complete coverage, it is unnecessary to detail further the reasons why a small minority interest can nullify the objectives of scientific unit control.

It should not be inferred, however, that because a pool is not unitized completely that efficient operation and the ideals of conservation are necessarily thwarted.

The South Burbank Pool unitization plan, also discussed by Miller and Shea,[25] is a good example where minority interests, the Sinclair Prairie Oil and Gas Co. and the Champlin Refining Co., have operated in substantial harmony with the basic principle of operation adopted by the unitized group. These operators have benefitted by the unitized plan, but whether their benefit is greater because of their decision to remain out of the plan is a question that the writers are not in a position to answer.

(*d*) *Unit operation in condensate pools.*—Scientific unit control is absolutely essential to this new type of pool. The reasons are fully discussed on pages 23–27. Due to the lack of market for gas, the discontinuance to a large extent of the practice (in Texas) of blowing gas to the air, and to the greater expense of individual operation as compared to unit operation, it is not particularly difficult to unitize condensate pools. With changed conditions, such as a ready market for gas, the same difficulties would probably arise in attempts to unitize condensate pools as have occurred with respect to oil pools.

(*e*) *Divergent viewpoints—Small operator against large operator.*—The small operator frequently fears and distrusts the large operator. These fears being inherent to human nature are not peculiar to the petroleum industry. In the instance of unitizing oil pools, however, the writers believe that the fears of the small operator may be largely unwarranted. If the success of unit operation depended in a considerable degree upon one party getting the "best of the deal," the writers do not believe that such plans would receive the personal endorsement of virtually all of the leaders of the petroleum industry. Moreover, in the only unit project in which the writers have been associated, the South Burbank

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[22] Phillips, Frank., op. cit.

[23] Glassmire, S. H., op. cit.

[24] Report and Recommendation of the Petroleum Administrative Board. Re: Appeal of the Superior Oil Co. and the Amerada Petroleum Corporation from the general method of intrafield allocation in effect in Kettleman Hills North Dome field since May 1, 1934.

[25] Miller, H. C., and Shea, G. B., Unit Operation.

Pool, Oklahoma, we believe that the large operators exceeded the bounds of normal liberality in their attempts to allocate to the small operator his equitable share of the total.

In contrast to the views held by the small operator, the major and large independent operators may take the attitude that the small operator frequently desires to capitalize his holdings on the basis of "nuisance value" rather than upon their potential capacity to yield oil.

(*f*) *Rugged individualism.*—Quoting from Knowlton:[26]

"It is not difficult to understand why, until the last 10 or 12 years, operators were opposed to this plan. Oil men at this time were the most rugged of rugged individualists, and the wildcatter's gambling spirit was thoroughly instilled in them. From their very nature it can be seen that they would have no desire to exchange this game of chance with the possibility of big, quick profits for the stabilized business under unit operations. Considering this inborn gambling spirit; the fact that the price of oil was approximately $3.50 a barrel; that there was a ready market for all of it; that taxes were low, and that wells were shallow; it is not surprising that little thought was given to conservation and cooperation. The oil business was too busy making money. Few had time to consider the plan of unit operation, but the few who did consider it became staunch supporters of the plan, and when such men as Messrs. J. Edgar Pew, Judge W. P. Z. German, and W. N. Davis joined in thought with Dr. Doherty, many others were induced to listen."

The wildcatter should not be deprived of his reward for opening oil pools. Oklahoma, for several years, has given 15,000 barrels for a discovery right for opening new pools. The recent Nebraska discovery has focused attention on the prize of $15,000 for the first producing well in Nebraska to produce 50 barrels a day for a period of 60 days.

The writers feel that more inducements should be given wildcatters to open new pools. New pool discoveries should be given at least 100,000 barrels of oil.

(*g*) *Opinions of the leaders.*—The unanimity of the views expressed by prominent men in the petroleum industry leaves no doubt of their opinion regarding the feasibility and desirability of promoting the general adoption of unit operation. Few, if any, of these expressions go beyond the advantages of increased oil recovery at less cost. Generally they appear not to favor compulsory unit operation, although one at least—Wirt Franklin[27]—would apply the American principle of majority rule.

(*h*) *Necessity of unit operation in secondary recovery projects.*—In secondary recovery projects such as the one proposed for the Oklahoma City field, it would be impossible to conduct such operations in a manner equitable to all interests without complete unitization of both royalty and working interests.

(*i*) *Equitable apportionment to the various interests.*—The more recent development of technique for subsurface studies doubly fortifies the conclusions of Oliver[28] in 1932 relating to determining with reasonable accuracy the extractable acreage content. This should be especially true of new discoveries where the main objective of the preliminary exploration and development would be to determine the many factors that would lead to a reasonable estimate of the amount of recoverable oil in place beneath each tract. In this stage of the operation, the commercial production of oil would be of secondary consideration.

(*j*) *Unit operation necessary for proper control of salt-water-disposal systems.*—The cost of subsurface salt-water-disposal systems is sufficient to make the average oil operator reluctant to adequately take steps to prevent pollution. Unitization, however, offers an opportunity for all of the pool operators to devise a joint plan for salt-water disposal without exorbitant expense to each. Duplication of facilities are avoided in such plans. This type of unitization has met with general acceptance as exemplified by the Fitts and Edmond Pools in Oklahoma.

(*k*) *Reasons for slow progress in unitization.*—In view of the general endorsement by the industry of the benefits relating to efficiency, economy, and conservation that must necessarily accrue from the scientific unit control of oil pools, the writers believe that the slow progress that has been made in unit operation of oil pools can be explained in no other way than the people generally do not want to be "regulated." Frequently they want others regulated, but as a rule want nothing that will interfere with their own freedom of action.

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[26] Knowlton, D. R., p. 3, par. 4, op. cit.
[27] Franklin, Wirt., op cit.
[28] Oliver, Earl, op. cit.

## STATEMENT OF GLENN E. McLAUGHLIN, NATIONAL RESOURCES COMMITTEE

Mr. McLaughlin. My name is Glenn E. McLaughlin. I am a native of Oklahoma. I graduated from Colorado College and did my graduate work in economics at Columbia University and at Harvard University. I am the author of section II of part 1 of the report of the National Resources Committee known as Energy Resources and National Policy. My section of the report represented an economic analysis of the petroleum and natural-gas industries.

At the present time I am assistant professor of economics at Hunter College of the city of New York. Before going to Hunter College recently, I was industrial economist on the staff of the Bureau of Business Research at the University of Pittsburgh, a position I held for about 10 years. During 1937–38 I was economic consultant to the Pennsylvania Oil Industries Investigation Commission.

### A. TYPES AND EXTENT OF WASTE

1. Capital wastes and high-cost operation: Competitive development of oil and gas production in the absence of adequate State and Federal regulation has led to the drilling, equipping, and operating of an excessive number of wells, especially in areas of flush production. The most important source of capital waste probably lies in this overdrilling of oil fields. In the east Texas field alone it has been estimated that 3,000 wells would have been sufficient for production. Yet that great oil reservoir has already been punctured by 23,000 additional but unnecessary producing wells at an added cost in excess of $300,000,000. Moreover, it has been estimated that a further 7,000 wells will be sunk in that field. Capital wasted in east Texas as a result of that kind of competitive development allowed and encouraged by regulatory efforts will approach, if not exceed, $400,000,000. Moreover, a larger sum will be spent in operating these 30,000 or so unnecessary wells, so that waste of materials and labor in the east Texas field eventually may well exceed $1,000,000,000—to say nothing of the funds invested in extra storage and transportation facilities necessitated by flush production.

In many fields waste has been as great or greater—for example—in Oklahoma City field and in Illinois. But if for the country, in order to set a conservative minimum, we estimate that half of the wells drilled in the decade of the 1930's were unnecessary to recover the oil and gas produced, wastes in drilling and operation amounted to nearly 3.5 billion dollars. If the proportion of unnecessary wells now said to exist in the eastern Texas field—nearly eight of nine wells—be applied to the country, the waste for the 1930's would reach about six and one-half billion dollars.

Competitive development not only leads to unnecessary wells, but it means that all wells must be operated more expensively. The loss of resevoir energy resulting from the high density of wells requires that pumping be initiated at a relatively early stage in the life of a field. Moreover, the obtaining of the remainder of the recoverable crude takes more time, which in turn means extra labor and longer use of capital. These methods result in social waste and in the long run in a decreased company operating profit. In some fields the excess cost of obtaining oil under conditions of intense drilling has led to the bankruptcy of most operators. In the Oklahoma City field, nearly all operators failed, except some of the large concerns.

These capital wastes are worth avoiding, but capital is more or less replaceable. Even more serious to the Nation than these capital wastes is the waste of large quantities of natural gas and petroleum—irreplaceable resources.

2. Natural gas: For the period 1922 through 1934 the waste of natural gas at natural gasoline plants average 1¼ billion cubic feet of natural gas per day or a total of nearly 6 trillion cubic feet for the period. The waste of gas not even treated for the removal of gasoline—therefore, wastage at wellheads was probably more than twice as great, so that the total lost exceeded the total volume utilized. Great waste of natural gas occurred in the Panhandle Field in Texas during 1934 when more than a billion cubic feet of gas was blown to the air daily, at natural gasoline plants. Wastage of natural gas at gasoline absorption plants still amounted in 1937 to one-third of the volume treated in New Mexico and Oklahoma and to about one-fourth in Texas, whereas in West Virginia it had been cut to less than 4 percent.

While the waste of gas, especially dry gas, has been reduced by more effective State regulation and by connection of wells with markets, it is possible that half of the total taken from the earth is still being wasted, perhaps as much as 2.5 trillion cubic feet in 1938, divided roughly as follows: Wastage at natural gasoline plants and in transportation, 0.4 trillion cubic feet, wastage at oil wells, 1.1 trillion cubic feet, and wastage at gas wells, 1.0 trillion cubic feet. In terms of heat units this enormous quantity of gas is approximately the equal of 440,000,000 barrels of crude oil, that is, more than one-third the 1938 consumption, or the equal of 165,000,000 tons of bituminous coal, that is, nearly half the 1938 consumption of bituminous coal. Messrs. H. C. Miller and G. B. Shea on page 334 of their paper Tuesday noted that waste of gas probably continued to exceed consumption, which in 1938 totaled 2.3 trillion cubic feet.

Part of the tremendous waste of natural gas is intentional. The gas is blown into the air because of the lack of a market, because of inability or unwillingness to store it in the ground, because of the desire to obtain oil as soon as possible, or simply because the supply in a new oil pool is not expected to be great enough to warrant the construction of facilities to utilize it.

3. Crude petroleum: The proportion of oil left in the ground which can be classified as waste depends on the extent to which the most efficient methods are being used. Although variations in recovery depend more on the nature of the reservoir, there are significant variations which result from the use of more or less antiquated methods. It has been demonstrated by the United States Bureau of Mines that where the reservoir energy is wasted only about 10 percent of the potentially obtainable crude will be produced. Actual operating methods are estimated to recover from 25 to 35 percent of the oil, the variation depending largely upon the permeability of the sand.

By the general adoption of the most efficient known methods recovery probably would equal from 30 to 60 percent. Some of these additional portions of the reservoir can never be recovered if, after the use of inferior methods, the field is abandoned.

In the Texas Panhandle oil reservoir the waste of gas led to the permanent loss of from 400 to 500 million barrels of oil. In the hurry to produce oil the falure to conserve natural gas as a source of reservoir energy resulted not only in the loss of the natural gas but also in the leaving underground of a large percentage of the total reservoir supply of crude. The extent of the loss of the crude in a field depends more or less upon the degree to which competitive drilling results in the puncturing of the underground reservoir.

### B. CAUSES OF WASTES IN PRODUCTION

1. Legal system of land and subsoil ownership: One of the major causes of waste of oil and gas relates to the right of the individual landowner, with few exceptions, to "capture" all of the oil and gas which is produced from wells on his property. The migratory nature of oil, when the static-pressure balance in the pool is distributed by drilling, leads to a movement of oil in the direction of reduced pressure. Consequently a well can and often does drain reserves from adjacent property. In many fields the adjacent landowner has no effective way of protecting his subsoil mineral rights other than to drill offsetting wells as rapidly as possible. In the effort to recover the maximum of oil in the minimum of time a large proportion of the reservoir energy may be wasted. The speed with which new fields are brought into flush production makes it unlikely that adequate marketing facilities will be available for the accompanying natural gas until after large quantities of this field are blown into the air. The speed of production may be also the major cause of underground losses of both oil and natural gas. The alternative to competitive production is some kind of a system of scientific or unit-field operation in which the spacing of wells and the rate of operation are based upon efforts to recover a maximum proportion of the underground resources and to make most effective use of the lifting power of natural gas. The States of Arkansas, Louisiana, New Mexico, and Oklahoma have made limited but significant steps in this direction. Moreover, production would be held back until adequate marketing facilities were provided.

2. Small landholdings: The wastes resulting from the operation of the "right to capture" are accentuated in many fields by the smallness of individual landholdings. In suburban districts or even within incorporated communities the intensive efforts to recover oil have led to wells being drilled within a hundred feet of each other. Under such circumstances waste is excessive. One of the first successful efforts to restrict excessive drilling occurred in the city of Oxford, Kans., in 1928. This was followed by general adoption of well-spacing provisions in oil-producing States with some efforts at enforcing pooling of interests in well-spacing tracts.

Overdrilling of the new Illinois oil field is in large part attributable to the unrestricted operation of the rule of capture in a district of small landholdings.

3. Abundance of easily accessible resources: Waste also results from the fact that oil and gas fields are being discovered in a large number of States and that possible oil-bearing territory is still very great. In

the search for oil and gas the most easily accessible and richest deposits are likely to be removed first. Such practices lead not only to the removal of some of the best grades of crude oil as soon as discovered but also to the use of less costly equipment. The largeness of reserves of oil and gas leads to an emphasis on saving capital rather than the resources.

4. Overproduction and depressed prices: The abundance of possible oil-bearing strata and the inadequate restriction of drilling efforts lead to serious overproduction if a major oil field happens to be discovered in a period of business recession. Such a situation occurred in the Seminole field in Oklahoma in 1927 and in the east Texas field in 1931. The rush to drill wells in a new field is just as great in a period of depression as in a period of prosperity. If drilling operations and production are not restricted somewhat in relationship to the changes in demand, prices of oil and gas will fall, and efforts to conserve supplies of oil and gas are likely to be dropped. Producers have no time to save gas when there is a race between adjacent leaseholders to acquire a greater proportion of the more valuable crude oil, nor are efforts to conserve or use residue gas successful if there is competition among producers to withdraw natural gas from a field and produce natural gasoline from it. The possibility of obtaining part of the resource under another's property promises a greater reward than efforts to conserve the oil and gas already obtained.

During periods of overproduction marginal wells are likely to be shut down; and, if the price of oil threatens to remain low for some time, the wells may be abandoned and the equipment moved to more profitable areas. This practice results in substantial hidden loss in ultimate recovery from these abandoned wells; for, if prices had been somewhat higher, it might have paid to continue their operation or even to have installed improved equipment. Once oil wells are plugged, it may be impossible to open them up again after prices rise above their costs of operation. The abandonment of wells because of low price of crude has been estimated to constitute a considerable economic loss.

5. Inefficient methods: Probably in every oil and gas field in the country wastes result because of the use of inefficient methods and out-of-date equipment. The explanation may be related to the low price of oil and gas, to ignorance of the best geological and engineering advice, or to lack of capital, and hence inability to take a long view. The advantage of a new method is difficult to establish in the oil industry because of the uncertainty about what occurs in the reservoir. Only after considerable experimentation is a change made to the more up-to-date procedure. Thus, only within the last decade or so has the function of reservoir energy been fully appreciated, although experiments in some kind of control of the gas-oil ratio were made years before. Much has been done by some States in requiring that operators observe approved standards.

### C. CONTRIBUTIONS OF PRORATION

Proration has been resorted to by States as a means of controlling output and until recently all efforts to regulate oil and gas production have revolved around the production restrictions measures.

1. Restriction of production: Proration has reduced waste somewhat simply by restricting output roughtly to current market demand. Overproduction of oil and gas may lead to physical waste at the wells because storage and transportation facilities are inadequate or because the price is driven so low that markets cannot be found. Storage, even if possible, may result in evaporation of the more valuable fractions of the crude. Moreover, low prices may cause the closing down of marginal wells and the permanent loss of some reserves. In any case, restricted flow of wells usually leads to a better use of reservoir energy.

2. Partial use of best engineering methods: Proration also provides a system under which some kind of supervision may be exercised over the engineering operation of wells. Output can be varied from well to well somewhat in line with efficient recovery. It may be possible to regulate production so that more or less uniform pressures are maintained throughout the field and so that gas-oil ratios are controlled. Proration results in operation of wells under back-pressures at part capacity. Since operation at full capacity is usually wasteful of reservoir energy, this suppression of flush flow achieved by proration is some contribution to conservation. Grossly wasteful production practices have been greatly restricted in many areas. Moreover, measures usually contain spacing rules, which, under favorable circumstances, make it possible for wells to be located with some reference to efficient use of reservoir energy. Thus, proration has sometimes made it possible to stimulate unit operation, although the advantages are only a small part of those available under unit control.

3. Development of better methods: In addition under proration there is opportunity to try out new methods of flowing wells and of studying what occurs in the strata during production. Under the restricted flow imposed by proration, producers have gained much technical information concerning the utilization of reservoir energy.

### D. INADEQUACY OF PRORATION AND STATE REGULATION

1. High-cost production: Practically all proration laws reserve a certain minimum allowable output to each well and for a time the general procedure was to give all wells in a State the same allowables. Such proration regulations, based as they are on the individual well, have encouraged the drilling of unnecessary wells in order to get for a piece of property a greater share of the State allowable. In this manner proration has accentuated the waste of capital and high cost of operation, characteristic of competitive development. An attempted antidote has been sought in the form of drilling and spacing regulations, but, as will be pointed out the numerous exceptions granted by State regulatory agencies have failed in most fields to provide a rational, low-cost system of operation. Spacing regulations are usually the least effective where they are the most needed: that is, in fields composed of small tracts.

2. Inability to use best-known engineering methods: As an example of inability to use scientific advice under proration schemes, take simply the matter of number of wells needed to recover efficiently the oil from the great east Texas reservoir, a pool underlying nearly 135,000 acres. As already stated, an expert consulting petroleum geologist familiar with the field has estimated that 3,000 wells or 1 to

45 acres would certainly have been sufficient, although comparisons with Persian experience suggests the possibility that under unitary direction no more than 300 wells or 1 to 450 acres might have recovered the 1933 peak volume of 206 million barrels, if under controlled conditions it has seemed desirable to produce that amount. The Texas Railroad Commission, according to its own proration criteria and with allowances for small landholdings, decided upon one well to 10 acres, equal to 13,500 wells for the east Texas field. Yet the Commission was not only unable to follow expert engineering advice but was even unable to follow its own compromise plan. More than 26,000 wells have been drilled into the reservoir and well density has risen to 1 well to about 5 acres, with present prospects for another 7,000 wells and a density of 1 to 4 acres. In other words, under proration the Texas Railroad Commission was forced to grant exception after exception to its own orders because of the pressure of small landholders for offset wells, until the density of wells probably exceeds what would have occurred with no regulation at all. Seventeen thousand of the first 24,000 wells were drilled under exceptions allowed from the railroad carrier's original spacing rule.

One of the major sources of difficulty concerns a tract whose acreage is too small to be granted even one well—a common condition in east Texas and indeed in most fields. Rigid adherence to spacing rules without some compensation to the owner for oil beneath his land would clearly be confiscatory; on the other hand, granting permission to drill a well without protection to neighboring landholders against undue drainage would also be confiscatory. As a solution, Texas adopted a plan whereby the owner of a small tract was granted a well and whereby the well density on a neighboring tract could be equalized. This plan, coupled with the interpretation of the Marginal Wells Act giving a full marginal-well allowance—in accordance with depth—to any well drilled on small tracts, resulted in a virtual abrogation of spacing regulations.

Overdevelopment of pools brought in by proration may result in well allowables too small to permit an efficient rate of flow, especially for the wells with higher pressures. Only slight consideration can be given to the acreage content; that is, estimated oil in place under the property surrounding a well. In east Texas until recently about 98 percent of the district allowables set for the field by the Texas Railroad Commission in dividing up State quotas were used up in the minimum prorations per well of about 20 barrels set by the Commission under the State's Marginal Well Act. Under such conditions, there is little possibility of basing proration on acreage content and if the actual rates of flow are consistent with efficient recovery it is purely an accident. Although the Federal courts have declared that the allowables for a good well must be higher than that for a poor one, the railroad commission has felt itself forced under the Marginal Well Act to deal with over three-fourths of the State's allowable on a basis which ignores any distinction between reservoir conditions or most efficient rates of production—this in a State which accounts for two-fifths of national oil production and more than half of known reserves. Conservation requires the maintenance of uniform reservoir pressures, and the adjustment of the allowable per well upon the basis of careful measures of comparative pressure declines. Some States try to follow this procedure, but it must be so drastically modified by the blanket allotments to all wells as to become practically a uniform allowable, with only minor considerations for differences in reservoir conditions and the acreage per well. A significant case is now pending before a three-judge Federal court in Texas, in which the Humble Oil & Refining Co. is seeking an injunction to force the Texas Railroad Commission to reduce the blanket per well allowables and to give more emphasis on oil in place. These paragraphs have related mainly to the State's inability under proration laws to space wells in a scientific manner; in many other respects, proration or production restriction is equally inadequate. No provision is made for requiring that a pool be developed under best engineering and production procedure to the end that a maximum amount of oil and gas is recovered with most efficient use of the reservoir energy. For example, proration laws provide no means whereby an operator with a well on the gascap can be kept from producing gas and wasting the reservoir energy. By not restricting the operator, the State is allowing him to raise the costs of production on the rest of the dome and to waste a part of the oil which could have been flowed to the surface but cannot be pumped or obtained by repressuring. Under proration, effective scientific control is not possible.

Earl Oliver, prominent appraisal engineer, in the last issue of the Transactions of the American Institute of Mining and Metallurgical Engineers, division on petroleum development and technology, states the case with respect to proration:

> Any use of proration in the manner now exercised between properties draining from the same reservoir—except as an emergency measure until some better method can be devised—must inevitably bring down upon the oil industry, consuming public, and Government itself evils out of all proportion to the benefits derived. These results may be summarized as follows:
>
> 1. Proration in its present form has to its credit that it has maintained a living price for oil; this in itself is a worth-while accomplishment, but its mechanics are such that:
>
> 2. It is perpetuating the high-cost production methods that have characterized the oil fields of the United States from the beginning of the industry and tends to hinder widespread application of the improved technology now available.
>
> 3. Proration built on the capture rule tends in turn to stimulate and then eliminate the independent refiners and markets of oil, induces "hot oil" running with all its attendant evils, creates situations resulting in "Madison trials," and in general promotes inequalities, inequities, and dissension within the industry.
>
> 4. It is gradually but inevitably leading the oil industry into complete Government management through Government's unsuccessful attempts to correct the evils arising out of 2 and 3 listed above, and thus is placing upon the Government functions that are inconsistent with its real purpose and that can be exercised more efficiently by the industry itself provided sound proration methods are installed.

Mr. Oliver is one of the foremost advocates of scientific pool control.

### E. LIMITATIONS OF STATE LEGISLATION

Under recent laws of New Mexico, Oklahoma, Louisiana, and Arkansas, pooling of mineral rights within well-spacing units can be required, under some circumstances, by the State regulatory commission. This step in the direction of conservation is well and good as far as it goes. But owing to the interstate character of the oil industry and the competition between States, such efforts cannot provide a full solution. Even if thoroughgoing conservation laws finally are established in a State, no effect can be exercised over wasteful flush production in another State. In fact poor standards are more likely to lower good standards than the reverse. Only Federal authority can resolve differences and conflicting interests among the States and thus assure on a Nation-wide basis adequate conservation of problems. Only by Federal action—potential or exercised—can uniform standards be achieved and can comparative output among States reflect the best conservation of reserves.

By dint of excessive competitive drilling with all its wastes Illinois is now the fourth State in quantity of oil produced. The unregulated, flush flow of the State's limited reserves is a catastrophe. With less than 2 percent of the Nation's reserves the State in September produced in September 10 percent of the oil. By January, Illinois may rank third in output, but probably in another year or two Illinois will drop back to eleventh place—a position it occupied in 1937 before the recent unfortunate boom. Only adequate laws, passed in advance of discovery, can avoid repetition of such waste, if, as in Illinois, a flush pool is discovered in a State with no conservation laws. Indeed, the whole story may repeat itself soon, for a discovery well has just been brought in in Nebraska, a State which has not passed regulatory measures and is not likely to do so, once the race of competitive drillings gets under way.

### F. REQUIRED MINIMUM ENGINEERING STANDARDS, INCLUDING UNIT CONTROL

If oil and gas are to be scientifically produced—and by that is meant, the maximum recovery of limited resources—the Federal Government acting in the national interest should do its part to see that in all oil and gas fields, new and old, of all States, certain minimum engineering standards are observed and that waste—that is, avoidable loss—is eliminated. One of the most exemplary sets of provisions are those adopted this year by the State of Arkansas. New Mexico and Louisiana also have comprehensive conservation laws. It is difficult to see, however, how full conservation can be achieved short of provision for scientific unit control. Compulsory integration of interests within well-spacing or drilling units is provided for in the 1939 Arkansas statute—clearly a step toward field-wide unit operation with the opportunity of adopting, not simply minimum engineering standards, but the best known field methods.

### G. UNIT OPERATION AS ONE SOLUTION

Unit operation is the most thoroughgoing solution to the problem of waste—a solution used but rarely in this country, outside of Federal lands.

1. Description: By unit operation is meant the development as a whole of a geological unit according to a definite program, royalties to be shared on the basis of acreage, oil in place, or some equitable arrangement regardless of the location of producing wells. In effect, unit operation is the opposite of the present competitive system of

wastefully developing oil fields. The major characteristics of unit operation are preliminary exploration in the case of new fields, compulsory pooling of interests, proper well spacing, acceptance of standard development and production methods, controlled withdrawals, and general scientific control. Although unit operation may be established in old pools and even in new pools without preliminary study of reservoir conditions, careful definition of the pool limits and of the nature of the reservoir are desirable preliminaries.

Effective unit operation requires the compulsory pooling of both operating and lease interests. The States have prescribed methods for the extraction of oil and gas from a common pool to protect the public interest against waste, and to insure a just distribution among collective owners.

Under unit operation wells would be spaced according to the conditions of the reservoir without any regard to property lines. Offset drilling, of course, would be abolished. Unit operation would make it possible to begin operations with a few wells and to drill additional ones as the more complete discovery of reservoir conditions made such action advisable.

Within a field all operations would be governed by proper methods. The same production procedure would be followed under comparable conditions. Moreover, withdrawals from the reservoir could depend upon changes in reservoir conditions and not upon any necessity of avoiding drainage to adjacent properties. Maximum recovery could be accomplished by coordinated operation of wells.

2. Major advantages of unit operation: While unit operation facilitates the general adoption in an oil field of the best current engineering and production practices, it does not, of course, guarantee these practices, since they are partly a result of effective governmental regulation and of intelligent local management. Preliminary exploration can discover the extent and nature of the pool, and continued measurements can give a guide to the most effective production procedure. Unit operation, for example, will allow production at various rates, the use of wells for somewhat different purposes, the spacing of wells in relationship to the contour of the pool, the abandonment or shutting in of wells as water or gas ratios become excessive, and the adoption of pressure maintenance or other secondary methods of recovery. Superior engineering procedures applied under unit operation make possible the conservation of reservoir energy and maximum recovery of oil.

Thus unit operation can lead to the reduction of production costs by eliminating unnecessary drilling, by maximum utilization of reservoir energy for lifting oil to the surface, by avoiding a high initial peak in capital investment and surface-plant equipment, which is ordinarily in use only a short time, by avoiding a similar peak demand for auxiliary services, such as roads, water supply, and staff accommodation, and by offering possibilities for research and constant checking on production methods.

By greater preliminary exploration, unit operation tends to increase known reserves. This substitution of greater proven reserves for the usual flush production results in savings of storage tanks, the avoiding of evaporation losses, and in considerable measure the elimination of fire risks. Moreover, excessive products may be returned to the reservoir. Unit operation possesses a further advantage in that it sets up an arrangement by which production can be easily and scientifically restricted. Production quotas can be allocated among pools, and the question of the production of the pool's allowed amount can be determined from the viewpoint of efficiency by the pool's management. It would presumably never be necessary to restrict unduly the production of any well, because the drilling of an excessive number of holes, such as occurs under flush production, would be avoided.

For the individual property owner unit operation is desirable because it facilitates remuneration according to a more accurate determination of oil in place and leads to a greater recovery of this oil and at lower costs. Thus, in the long run, his net return should be almost always greater than under a system of competitive drilling.

3. Extent of adoption: Unit operation is invariably practiced in those countries where mineral rights are the property of the state or where concessions covering large areas are given to single operating companies. Thus, in the major fields of Iran (Persia) and Iraq unit operation is practiced by the foreign oil companies holding state concessions. It is also used in parts of Venezuela, where foreign oil companies hold large contiguous blocks of leases.

The advantage of compulsory unit operation is considered so great that England, in making provision for any possible oil field which may be discovered in Great Britain, has provided in the British Petroleum Regulations of May 14, 1935, for cooperation among lessees of one geological unit, to be effective at first voluntarily, failing which the Government, through the board of trade, has the power to require unit operation subject to the right to arbitration.

Voluntary unit operation has been practiced in the United States for many years, and particularly since about 1927, when a period of overproduction stimulated interest in unit control as a stabilization device. Yet less than 200 pools or sections of pools are operated under some kind of unit management at the present time, and these make up a very small percentage of the total production.

Many of the more important unit schemes in the United States involve Federal land. One of the first major legislative moves in the direction of unit operation in the United States was the enactment by Congress of laws applying to lands belonging to the United States.

In a very restricted manner unit operation has been adopted and approved by the laws and regulations of Arkansas, Oklahoma, New Mexico, and Louisiana, in the sense that pooling of mineral rights within well-spacing units can be required by the regulatory authorities of the States. The drilling district or proration unit seems to be a step in the direction of compulsory unit operation of the entire pool. All that seems to be necessary is that the State require that the wells in adjoining drilling districts be operated according to standard regulations and that some methods be found of compensating the owners of the gas cap.

4. Widely recommended: Unit operation of oil and gas pools has been widely recommended by geologists and engineers, oil producers, lawyers, economists, and Government regulatory bodies, and in most of these instances compulsory unitization was recommended. In their opinions, unit operation presents no insuperable problems.

5. Accomplishments: The greatest achievements of unit operation are those in Persia and Iraq. The fields in those countries have pro-

duced a much larger percentage of their oil by natural means—that is, by use of reservoir energy—and have been characterized by costs considerably less than those in the United States.

Earl Oliver and J. P. Umpleby, petroleum engineers, further state that the greater part of foreign oil is produced from large blocks with the competitive feature either absent or very materially reduced, whereas most American oil is produced under competitive conditions of waste and high cost. V. R. Garfias and R. V. Whetzel, of the Cities Service Co., have recently pointed out that some American fields are so uneconomically exploited as a result of the operation of the "law of capture" that the oil produced would not be able to compete outside the country with foreign oils. The greater advantage of unit control is illustrated by the operation of the Anglo-Iranian Oil Co., Ltd., of the Masjid-i-Sulaiman (Temple of Solomon) field in Persia. From February 1929 to the end of 1932, according to Sir John Cadman, chairman of the board of the Anglo-Iranian Oil Co., no well in that field—

> has ceased natural flow on account of declining pressure or of diminished drainage from the reservoir rock. No well has been taken off production on account of edge water encroachment, nor, indeed, has edge water been produced in any production well. A certain number of wells have gone to gas and been closed in, but this is strictly in accordance with our system of operation; the dates on which such wells have gone to gas have corresponded closely with estimates existing 4 years ago, and replacement wells have, where necessary, been methodically completed in advance of these dates. The pressure in the gas dome of the Masjid-i-Sulaiman field has dropped only 5 pounds per square inch—approximately 1 percent—during the past 4 years, although a production of nearly 20,000,000 tons has been drawn from the field during that period.

(A ton equals about 7.6 barrels.)

Sir John Cadman has attributed these achievements largely to unit operation, supported by adequate engineering standards.

The average production per well in the Kirkuk field in Iraq and in the Haft Kell field in Iran (Persia) in 1935 was nearly 50 times the average production per well during conditions of peak production in 1933. Nearly 12,000 wells in east Texas were used to obtain a production of 205 million barrels in 1933, whereas in the Kirkuk field 45 wells were sufficient to produce 27 million barrels of oil in 1935, and in the Haft Kell field 40 wells were sufficient to produce 27 million barrels in the same year. And even some of these wells were operated for observation and definition of the pool—in the Kirkuk field all but 14 were exploratory wells.

Significant achievements of unit operation in the United States have been made in the Kettleman Hills field in the San Joaquin Valley, Calif., in the Belvedere Gardens and Dominguez Hills field in southern California, in the Van, Yates, and Sugarland fields in Texas, the Hobbs field in New Mexico, and the South Burbank and other Osage County fields in Oklahoma. The difference in costs of production between fields developed cooperatively, and those developed competitively is impressive. Kettleman Hills is not an example of thoroughly successful unit operation, mainly because unitization was not complete. The small noncooperative outside interests caused much unnecessary waste; practices existed which would not have occurred under full unit operation. On the other hand, partial unitization made it possible to avoid many wasteful methods. It is not by accident that the lowest operating costs among California fields, 1931 to 1934, were those for Kettleman Hills, and the next lowest, those for Dominguez.

To conclude: The Nation's reserves of oil and gas are both limited and irreplaceable. Current estimates indicate that oil in sight is equivalent to about 11½ to 14 times the 1938 production but the upward trend in consumption makes it likely that the quantities taken from the earth in the next 10 years will exceed our present proven supply. Estimated life of known gas reserves in terms of 1938 output varies from 30 to 40 years. In spite of this limitation of supply, waste is excessive. Rarely are oil and gas produced with the aim of recovering the maximum proportion of the reserve. The best engineering practices can be adopted only under coordinated pool operation.

As a means of conservation, scientific unit control provides an unexcelled opportunity. Surely, some legal and economic arrangements can be devised for its general introduction into American oil field practice.

Mr. Kelly. We thank you and the committee will stand adjourned until 10:30 o'clock Friday morning.

(Thereupon, at 4:30 p. m., the subcommittee adjourned to meet Friday morning, November 10, 1939, at 10:30 a. m.)

# PETROLEUM INVESTIGATION

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FRIDAY, NOVEMBER, 10, 1939

House of Representatives,
Subcommittee of the Committee on
Interstate and Foreign Commerce,
*Washington, D. C.*

The subcommittee reconvened, pursuant to adjournment, at 10 a. m., in the committee room, New House Office Building, Hon. William P. Cole presiding.

Mr. Cole. The committee will come to order. At this time we are glad to hear the Secretary of the Interior.

## STATEMENT OF HON. HAROLD L. ICKES, SECRETARY OF THE INTERIOR

Mr. Ickes. Mr. Chairman and gentlemen of the committee, I appreciate greatly this opportunity to appear before you in behalf of H. R. 7372.

I regret that I could not be here earlier, but I have just returned to Washington from California. While there I joined Governor Olson in a radio broadcast in which I expressed my ideas of the Federal interest in the Atkinson oil bill, which was before the people of California on referendum last Tuesday. This bill had the support of President Roosevelt, the Secretary of War, the Acting Secretary of the Navy, the Secretary of the Interior, and many others, but it was defeated. Reports filed with the California secretary of state on October 30, 1939, show that $230,385.66 had been expended up to that date by those against the measure and $156,740.08 by those who favored it.

This action in California closes another chapter in the history of oil-conservation legislation, which began 61 years ago in Pennsylvania with the enactment of a law which required the plugging of abandoned wells to prevent the infiltration of water into the oil-bearing rock. The use of casings was required by Kansas in 1891 and by Texas in 1899 further to protect the oil-bearing sands from water.

The enactment, amendment, or extension of most of the oil and gas conservation laws can be attributed to legislative recognition of some noticeably wasteful situation. The Texas law of 1899 was enacted shortly after the discovery of the Corsicana field, and Texas has revised and broadened its statutes as subsequent practices at Spindletop, Ranger, and in other areas demonstrated the need for more stringent measures to prevent waste. The present Texas law was enacted in its primary form in 1931, a few months after the east Texas field was discovered. Oklahoma saw the need for legislation after the Glen pool was discovered, and adopted in 1909 the ratable-taking law, under which oil proration was begun in the Cushing field in 1914. Oklahoma enacted a new law in 1915, when practices in the Cushing field resulted in "insane waste," to quote the then chief conservation officer of the State.

As a consequence of the great waste that accompanied the development of the El Dorado and Smackover pools, the Arkansas Legislature enacted its oil and gas conservation law of 1923. Louisiana adopted its laws of 1920 and 1924 in recognition of waste in the Monroe gas field, and its 1936 oil-conservation law followed a year of waste in the Rodessa field. Arkansas needed to experience the waste caused by dissipation of reservoir energy in the Arkansas extension of the Rodessa field before enacting its present law earlier this year.

The earlier laws and regulations dealt with conditions or practices which were visibly wasteful or were inferred to be wasteful from that which could be seen, such as the storage of oil in open pits, the wasteful burning or blowing of gas into the air, and the escape underground of oil or gas through the use of faulty or defective casing. However, the definition of waste has become more inclusive, as research and experience have developed broader knowledge of the physical nature of oil and the factors affecting its recovery from the underground reservoirs.

Technologists of the oil industry added to their knowledge of underground conditions in oil fields by recording casing-head or top-of-the-well pressures and gas-oil ratios and translating them into an interpretation of underground conditions by comparison with the results of laboratory research. Even while this was being done, instruments were being devised and tested for obtaining facts as to the physical and chemical nature of the fluids at the bottom and other points in the well. By these instruments petroleum engineers were enabled to see what happened underground as oil and gas were being produced. With this broader scientific horizon, technologists of the industry learned and demonstrated the desirability of retaining natural gas in solution with oil and of maintaining reservoir pressures, as well as the contributions of each to the achievement of maximum recoveries of oil. The definition of physical waste contained in H. R. 7372 (sec. 5 (b)) reflects these scientific and engineering accomplishments of the industry. The tenor of that definition is that any avoidable and unreasonable method or practice is wasteful physically if it causes oil to be left underground which otherwise might have been recovered.

Legislatures, in the enactment of these laws, and the courts, in their interpretation of their provisions, have followed in the footsteps of an advancing technology, but not without incurring the stubborn opposition of those who have resisted the encroachment of new ideas and have opposed a change from practices to which they had become accustomed. Not only has there been a perceptible lag between the unfolding of new ideas and their application by oil producers generally but new ideas, when advanced, have been subjected frequently to the accusation of being merely theory and speculation.

Well known in this connection is the three-judge Federal-court opinion given in 1931 in the *MacMillan* case against the *Texas Railroad Commission* in the western district of Texas. Here the court held that the plaintiffs had established that the proration plan of ratable and moderate withdrawals to control the encroachment of water and increase the recovery of oil, set out in the Commission's order of April 1931, was "largely theory and speculation" in the light of the then present knowledge.

The use of mud-laden fluid in drilling to prevent the waste of gas is accepted in present practice and is required in the regulations of many of the oil-producing States, but it was different 25 years ago when engineers of the Bureau of Mines, who had gained their experience in California, endeavored to demonstrate the method in the oil fields of Oklahoma. Trade journals of the period reveal that this effort of the Bureau was "widely ridiculed." The oil companies were said to be "fearful of, and opposed to, any movement for gas conservation."

These men were in Oklahoma because Secretary Lane had written to Governor Cruce on December 16, 1914, offering the services of Bureau of Mines experts to cooperate with State officials in stopping the waste of natural gas in Oklahoma. The offer was accepted by Governor Cruce in his letter of December 21, 1914, in which he said:

> The laws of Oklahoma are entirely inadequate to deal with this subject. At the recent session of the legislature I recommended that the laws on conservation of gas be remodeled so as to make it possible to protect from waste the gas of the State. The oil interests, however, were sufficiently powerful in the legislature to prevent any adequate enactment upon the subject.

The Bureau of Mines assisted in drafting the two laws on oil and gas conservation which were passed by the 1915 Oklahoma Legislature. The law was supported by four associations of independent oil producers who probably represented, as claimed, less than 20 percent of Oklahoma's oil production. It was opposed by an association which represented the larger oil producers. The president of the opposing association described the measure as the "most drastic legislation ever presented." The gas-conservation law which followed the oil law was described in one of the oil journals as "another radical measure" and as a "freak bill." For their assistance in drafting the gas-conservation bill the Government's experts were charged with "meddlesome interference with State legislation."

The Oklahoma oil law of 1915 has been described as a "paper law" and as a "dead letter statute." Before the year was over the Cushing field had declined sharply in production, demand had increased, and prices had advanced. The Commission's order of June 5, 1915, for preventing waste of crude oil and natural gas in the Healdton field was suspended for 2 weeks near the close of the year, upon petition of the producers, and thereafter was neither revoked nor renewed. Little attention was given the law thereafter for more than 10 years. In fact, it seems to have been forgotten completely in 1923 and 1924, when most of the operators in the Tonkawa, Burbank, and other pools in Oklahoma attempted, without reference to the law, to limit drilling and new connections and to reduce the runs from the wells.

Despite this, the 1915 Oklahoma law has been a beacon in the history of oil conservation. It was the pioneer effort, east of California, in the recognition of underground waste. Many oil wells of that period were drilled and cased improperly, and, upon abandonment, plugged improperly, allowing oil and gas to escape from one stratum to another and permitting water from other formations to penetrate and flood the strata containing oil and gas. It was this waste which the framers of the Oklahoma law of 1915 had in mind when they included "underground waste" in their definition of waste. They were unaware of the underground waste resulting from the inefficient use of reservoir energy or from excessive gas-oil ratios. As an interesting sidelight, the first graduates in petroleum engineering in this country were awarded their degrees at the University of Pittsburgh in 1915, the year in which the pioneer Oklahoma law was enacted.

Subsequently, "underground waste" was recognized and included in the Louisiana law of 1918, the Arkansas law of 1923, the Texas law of 1925, the Kansas law of 1931, the Michigan law of 1931, and the Missippi law of 1932. A broader concept of underground waste was recognized legislatively in 1931 when Texas added the unnecessary, inefficient, excessive, or improper use of the gas, gas energy, or water drive to its definition of waste and Kansas did likewise as to the waste of gas energy. The more recent conservation laws—those enacted in New Mexico and Oklahoma in 1935, Louisiana in 1936, and Arkansas and Michigan in 1939—include the waste of reservoir energy in their itemized definitions of waste in oil production.

Twelve years after the 1915 law oil producers in Oklahoma had a further opportunity to consider legislation to conserve oil and gas. In January 1927 a bill to conserve natural gas was introduced in the Oklahoma Legislature under the sponsorship of Mr. E. W. Marland, later elected to the Congress and as Governor of Oklahoma. Its purpose was to—

> prohibit and prevent the waste of natural gas * * *; to prolong the period of use of natural gas for light, fuel, and power purposes * * *; to increase the amount of oil recoverable from the sands by maintaining and utilizing the gas pressure in oil wells for a longer period, and by returning natural gas to the sands for the purpose of building up depleted pressure in oil wells and thus further increasing the percentage of oil recoverable from the oil sands in the various fields * * *.

The provision as to gas-oil ratios was the principal feature of the bill. Section 11 was as follows:

> It shall be the duty of the Corporation Commission of the State, by order or orders, to establish a proper oil-gas ratio for each field, or pool, sand, or well, in each field producing oil in this State, specifying the quantity of gas, less or greater than 500 cubic feet, which may be taken or permitted to escape from any well in said field, pool, or sand for each barrel of oil produced by said well; and in establishing said oil-gas ratio said Corporation Commission shall so fix the same as to preserve to the greatest extent and for the longest time practicable the gas pressure in said field, pool, or sand, retard as long as possible the encroachment of water upon the oil sand, extend the oil productive life of the same, and thereby increase as greatly as possible the ultimate recovery of oil from said field, pool, or sand.

A committee of 15 oil producers, in a report to the executive committee of the Oklahoma-Kansas division of the Mid-Continent Oil and Gas Association in February 1927 concluded that this bill was "revolutionary, drastic, and dangerous, unsound in principle, and unworkable in practice" and the oil-producing industry in Oklahoma was urged to oppose it. Fourteen of the 15 members signed the report. The minority of one was Mr. Marland's representatives on the committee. Here are some statements taken from this majority report:

> Necessarily and in its nature, the establishment of an oil-gas ratio for a given pool, much less for a given well, is arbitrary and will result in confiscatory discrimination. It is humanly impossible for any man, no matter what is his education and experience, equitably to apportion the amount of oil each operator shall recover in a given pool.

The proposal to produce oil on an arbitrary fixed oil-gas ratio is contrary to engineering theory. The proposal of the theory is comparatively recent and, consequently, the method is in the experimental stage. As a theory it is not even accepted or approved by the majority of petroleum engineers.

The industry in Oklahoma and elsewhere is spending vast sums in conducting numberless experiments and research for the sole purpose of improving methods and developing higher efficiency in oil and gas production. Equal consideration and study is being given the utilization and greater conservation of oil and gas. Production methods are constantly being improved and advanced. State control will hamper and retard rather than promote and advance progress.

Hearings on the measure were held before Senate and House oil and gas committees of the Oklahoma Legislature. The bill did not become a law.

It is not surprising that oil producers of that period should have been opposed so strongly to the conservation of natural gas when produced with oil. With a few notable exceptions, such a viewpoint was traditional among oil producers. Years earlier, the Bureau of Mines had reported that "the main purpose of the oil producer is to get the oil and let the gas escape."

Several of the early laws prohibited the blowing of natural gas in the air or burning it in open flares in the field but some of them, such as the Kentucky law of 1892 and the Texas law of 1899, provided specifically that prohibition against the waste of natural gas should not apply to gas escaping from any well while it was being operated as an oil well. Oklahoma, in 1905, attempted to limit the amount of natural gas produced with oil by providing that the prohibition against such waste should not apply when the production of oil had a greater available market value than the production of gas. Louisiana adopted a similar provision in 1910. A statutory value was placed upon such gas in 1924, when a law was enacted in Louisiana which included a provision that gas should be valued at 3 cents per thousand cubic feet in determining the value of gas production in comparison with oil. On this basis, if a barrel of oil had a field value of 90 cents, 30,000 cubic feet of gas could be produced with each barrel of oil before statutory waste occurred. Such legal provisions obviously took account only of the fuel value of the gas at the surface and did not consider the value of natural gas underground as a factor in the production of oil.

In connection with this Louisiana limitation of gas-oil ratios, as expressed in its 1924 law, an examination of the reports filed by oil producers with the Louisiana Department of Conservation shows that eight oil wells in the south Louisiana fields were operated during July 1939 with gas-oil ratios in excess of 30,000 cubic feet per barrel of oil.

A committee of nine, appointed by the Federal Oil Conservation Board to consider a legislative program for the conservation of oil and gas resources, reported on January 28, 1928. This committee supported the conclusions of the technologists of the oil industry as to the need for the conservation and efficient utilization of natural gas in preventing underground waste and increasing the ultimate recovery of oil, but encountered its principal difficulty in determining how such conservation could be brought about. The committee visualized many practical difficulties in the event that a State authority should impose on the owners and operators of a field a plan for its common development and production to which they might not all agree and described such procedure as a "drastic and difficult expedient." Instead, the committee supported voluntary agreements for cooperative development and operation and recommended the enactment of Federal and State legislation which would authorize such agreements. About 4 months prior to the date of that report, producers in the Yates pool in Texas had entered into a voluntary agreement under which a curtailed production was distributed among the operators upon a common basis.

In the succeeding 3 years, 4 laws were enacted which authorized agreements for the cooperative development of oil fields. New Mexico was first in 1929; the Federal Government was second with 2 laws in 1930 and 1931, authorizing the approval of agreements in operations on public lands; and California followed later in 1931. These laws furnished an opportunity in 2 States and on the public lands for the oil industry to follow the committee's recommendation, but little was done thereunder. One formal proration agreement, that for the Hobbs field involving private, State, and public lands, was approved under the New Mexico law; 11 agreements were approved under the 2 Federal laws; and in California 3 tentative plans for the cooperative development of fields on State and private lands were submitted but their final approval never was requested.

The 1929 law in New Mexico was superseded by that State's conservation act of 1935. The Federal oil and gas leasing laws were amended on August 21, 1935, and the Secretary of the Interior was authorized to require agreements for unit operation. Under this authority 112 agreements have been fully approved.

In the same year that the committee appointed by the Federal Oil Conservation Board described the application of State authority to plans for the common development and operation of oil fields as a "drastic and difficult expedient," the Railroad Commission of Texas issued its first proration order, that for the Hendricks pool in Winkler County. Since then State authority in this respect has been applied widely. Each of the oil fields now producing in Texas is operated under an order of the Railroad Commission, and in the other seven States which have enacted oil-conservation laws the authority of the State is exercised in regulating the development and operation of oil fields, although the extent and manner of doing so differs from State to State. Although opposed by many a decade ago, this application of State authority now appears to be acceptable to oil producers generally.

The current Louisiana law empowers the commissioner of conservation to require the operation of wells with efficient gas-oil ratios, to require the installation and use of approved devices to lower gas-oil ratios to prevent waste, and to fix such ratios. Under this authority maximum gas-oil ratios have been established in special rules issued for some of the oil fields in northern Louisiana but maximum ratios, or other special field rules, have been established for only one field in southern Louisiana. Operators' reports filed with the Louisiana Department of Conservation show that 123 oil wells in southern Louisiana were operated during July 1939 with gas-oil ratios in excess of 5,000 cubic feet of gas per barrel of oil produced. These wells produced 376,000 barrels of oil and 3,804,000,000 cubic feet of gas, an average of about 10,000 cubic feet of gas per barrel of oil.

Texas has adopted a State-wide rule which sets a maximum gas-oil ratio of 2,000 cubic feet per barrel of oil, which may be varied only with the approval of the Railroad Commission of Texas. Lower limits are set in some fields, such as the East Texas field where the maximum gas-oil ratio is 500 cubic feet per barrel of oil. Arkansas also has adopted 2,000 cubic feet as the "gas limit" for oil wells in a number of fields, under rules which have been issued by the Arkansas Oil and Gas Commission. The Kansas Corporation Commission has promulgated two orders which prescribe maximum gas-oil ratios, one in December 1937 of 3,000 cubic feet, applicable to the Otis field; and the other in January 1938 of 5,000 cubic feet, applicable to the Burrton field. The Kansas Corporation Commission rescinded this order for the Burrton field on October 26, 1939, because of the almost complete exhaustion of the gas. In this connection, it was reported that—

> Some representatives of the commission are inclined to believe that if gas conservation had been enforced from the first, this field would be an important source of production of this natural fuel today.

The Oil Conservation Commission of New Mexico is authorized under the 1935 law to require the operation of wells with efficient gas-oil ratios, and to fix such ratios, but no State-wide order has been issued, nor have special rules for particular fields been adopted to limit the quantity of natural gas produced with each barrel of oil. Current reports show that 40 percent of the oil wells in New Mexico are operated with gas-oil ratios in excess of 2,000 cubic feet, the State-wide maximum adopted by Texas.

However, the New Mexico Commission has given some attention to gas-oil ratios in that State. At a meeting in Santa Fe on July 22, 1938, called for the purpose of discussing the gas-oil ratio problems in southeastern New Mexico, one member of the Oil Conservation Commission is reported to have expressed his approval of what had been done but pointed out that this was only a small part of the work that should be done. He stated that the commission was willing to assist in every way but that the majority of the operators had not taken the matter seriously in the past and unless every possible measure was taken to correct high gas-oil ratios, the commission would be forced to adopt a maximum gas-oil ratio for the various fields. Information available at that time, covering operations during May 1938 showed that 275 wells in New Mexico were operating with gas-oil ratios in excess of 5,000 cubic feet of gas per barrel of oil produced. The corresponding report for July 1939 shows that this number had been increased to 331. This represents from 15 to 17 percent of the wells included in the report of the Lea County operators committee. (This committee in 1937, with the approval of the Conservation Commission, replaced the earlier Hobbs proration committee and was made the coordinating agency of all proration activities in New Mexico.)

The Oklahoma Corporation Commission has issued only one order establishing a maximum gas-oil ratio. This order of September 11, 1937, applied to the Moore pool and limited gas production to 4,000 cubic feet per barrel of oil produced. The Moore pool had a total estimated recoverable reserve of 20,000,000 barrels of oil and, by September 1, 1937, approximately 15 percent of this amount had been produced while the bottom-hole pressure had declined 55 percent and gas-oil ratios had increased. The commission found that this decline in bottom-hole pressure with respect to the oil recovered had resulted from an inefficient use of reservoir energy and was creating waste within the contemplation of the Oklahoma law. It found also that not more than 50 percent of the estimated recoverable oil would be produced with the available gas energy contained in the reservoir. The commission thereupon set an upper limit of 4,000 cubic feet to the gas-oil ratio, which was slightly higher than the average gas-oil ratio in the pool at the time of the order.

Following this order the Oklahoma commission issued a number of monthly reports of gas-oil ratios and bottom-hole pressures in the Moore pool. These reports show that during the year following the issuance of the commission's order many of the wells in the pool were operated with gas-oil ratios in excess of the maximum established by the commission and that the bottom-hole pressure continued to decline. The original pressure was given as approximately 2,837 pounds per square inch; as of September 1, 1937, it had declined to an average of 1,269 pounds per square inch and by June 1938 to an average of 845 pounds, an over-all decline of nearly 2,000 pounds, or an average of approximately 2½ pounds daily. This daily rate of decline in bottom-hole pressure is twice that recorded for the Fitts pool in Oklahoma, which was referred to recently at the Temporary National Economic Committee oil hearing as a "poorly controlled field."

This presentation of some of the high lights of the history of oil conservation in the United States has been prepared from information available in the Department of the Interior. The indications of wasteful practices which have been mentioned support the conclusion that the enactment of an oil-conservation law by an oil-producing State, or even by all of them, does not of itself assure the prevention of waste. The interest, initiative, and integrity with which these laws are administered are factors which really determine the effectiveness of these waste-prevention statutes.

The testimony presented to your committee by the Interior Department has reviewed the engineering and scientific accomplishments of the oil industry. Technologists have been successful in developing and testing improved methods for finding and producing oil. This work is a splendid contribution to the achievements of American science. But when attempts are made to correlate this scientific and engineering attainment with its application to the ordinary, everyday business of producing oil, varying degrees of interest or indifference will be noted. Mr. Robert E. Hardwicke, an attorney of Fort Worth, Tex., has said:

> The ordinary operator, and most of the executives of the major companies, were too busy prior to 1930, and profits were too easy to make, to cause them to pay much attention to the geologist and petroleum engineer who had urged more efficient production methods, and had branded as grossly wasteful the practice of producing wells in flush fields to capacity.

State Senator Clint C. Small, author of recent Texas gas conservation law, said at the July 1939 meeting of the Interstate Oil Compact Commission at Santa Fe, N. Mex.:

> One thing that is wrong with oil proration and gas proration is that too many people in Texas, Oklahoma, and New Mexico want proration and conservation in some places, where they are at a disadvantage and where they need protection from unscrupulous persons who are taking their oil and gas; but when the

> condition is reversed, and where they have the advantage, they stand out militantly against conservation * * *.

Mr. James A. Veasey, who appeared before your committee during its previous investigation, in an address before the Louisiana Bar Association in April 1939, said:

> No one who candidly faces the facts should have the temerity to assert that the State conservation agencies have done a thoroughgoing job of conserving the oil resources of the country. Oil conservation, through the exercise of State power, in the main, has been a haphazard, unscientific, poorly coordinated, and up-and-down enterprise at best. Then, too, neither California nor Illinois has enacted conservation legislation. In the other States the fault lies in the manner in which the conservation laws are administered and not so much in the inadequacies of the conservation statutes, although in the light of our present scientific knowledge some of these statutes decidedly could be improved.
>
> The responsibility for the failure of thoroughgoing conservation by the States rests partly upon the administrative agencies charged with that duty, but more largely upon the industry itself; because, as a rule, if united in counsel, the industry either controls or substantially influences the type of conservation orders made by the State agencies.

I have quoted these recent statements because the three gentlemen who made them are known widely throughout the oil industry as being associated closely with many of the State oil and gas conservation laws, either in their drafting, enactment, or application.

On the operating side, Mr. William S. Farish, president of the Standard Oil Co. of New Jersey, in his testimony last month before the T. N. E. C. said:

> Critics of the regulatory bodies must remember that appreciation of the need for conservation has been a slow growth in the minds both of men in the industry, and of the general public, and that general acceptance of this conservation principle has by no means been either simultaneous or universal.
>
> But there are some directions in which substantial improvement might be made. For one thing, more attention must be given to the proper spacing of wells to get optimum production in each field with minimum drilling expenditure. At the same time, it is also important to insist on higher standards of administrative procedure on the part of the regulatory commissions in order to stamp out the pernicious practice of granting special favors and exceptions.
>
> In general, State conservation and proration is a sound concept. Improvement in administration is possible. Elevation of purpose; clarification of objectives; and strengthening of personnel, standards, and procedure are all vitally necessary. Although there are valid grounds for criticizing many of the actions of the State commissions, I want to emphasize the fact that notable progress toward conservation has been made under this system. I am confident that this progress will continue.

I favor strongly the continuance of oil and gas conservation laws in the States which have enacted them and their adoption by the States which do not have them. It would be a serious mistake even to suggest that they be set aside, with the complete loss of all which has been accomplished during the past few years. Since 1936, I have sent many letters and telegrams to the Governors of Arkansas, California, Illinois, Louisiana, Michigan, and Mississippi, inviting their attention to pending oil bills and expressing the national interest in legislation which would tend to conserve the Nation's oil and gas resources.

The principal intent of such State laws, as enacted 20 or more years ago, was to equalize to some extent the opportunities of those engaged in oil production, when production exceeded the physical facilities for handling the oil. These were the so-called ratable-taking laws, designed to prevent a transporter from taking the oil of a few favored producers to the detriment of others. Subsequently, proration was regarded as a temporary expedient to limit the mass of production and to serve as an element of stabilization during periods of stress when actual or potential production exceeded the demand for oil. As the anticipated emergency period lengthened and changed gradually into an era of plentiful supply and as scientific investigations, supported by knowledge gained through experience, demonstrated that orderly methods of production made possible an increased recovery of oil, these laws began to be applied more widely as conservation statutes for the prevention of waste in oil and gas production.

Senator Small of Texas, in an address before the American Bar Association in 1938, described this recent trend to conservation in a vivid manner when he said:

> Out of the feverish activity and the genuinely sincere research that ensued, the petroleum industry and the public at large were forced to appreciate the enormity of irretrievable losses that were directly traceable to the unrestrained and uncontrolled production practice of the past. Out of the calamity that was so imminent and pressing from 1930 to 1934 has come an enlightened public sentiment that demands the application of sound engineering practices to prevent waste in the production of oil and gas. All of the recent converts to conservation will not remain steadfast in their newly adopted faith when the tide of oil turns and the supply fails to meet the demand, but many of those who came to stabilize will remain to conserve because they realize that if conservation is needed when oil is plentiful, it is indeed imperative when oil is scarce. The disregard for the rights of posterity has largely disappeared and in its stead we find a concept demanding protection against practices that will cause an unnecessary shortage of oil and gas in the future, which is indeed a healthy background for the necessary extension of conservation activity.

In its present meaning and in accordance with its dual purpose, proration is defined in the rules and regulations of the Corporation Commission of Kansas, September 1, 1939, as—

> the regulation of the amount of allowed production for the purpose or purposes of preventing waste, undue drainage between devolped leases, unratable taking, or unreasonable discrimination as between operators, producers, and royalty owners, within a common source of supply, or unreasonable discrimination in favor of any one pool as against any other pool in this State.

In contrast with the several purposes of State laws, the bill H. R. 7372 is designed solely to conserve petroleum and to provide for cooperation with the States in preventing its waste. It does not authorize the Federal Government to limit, on the basis of demand, the oil production of the United States, or of any State, field, or well. It does not permit the Federal Government to prevent or correct discriminations among property or royalty owners or producers within a single pool or between different pools within a State which may arise in the allocation of production among fields and wells by the State authority; nor does it provide that the Federal Government should regulate refining or marketing practices. It does not narrow or limit the existing State authority to do these things nor does it prescribe that any State should exercise its authority in this respect. For example, the Arkansas Legislature, in its consideration of the oil-conservation law enacted earlier this year, saw fit to eliminate all references to market demand in its definition of waste. If this proposed bill is enacted into law, it will not change that decision of the Arkansas Legislature, nor will it alter the action of any other State

Legislature which might have the same or a different attitude as to waste resulting from production in excess of demand.

The bill is designed to encourage and assist the States in the prevention of waste, not to restrict or limit their action in this accomplishment. The regulatory provisions of the bill would apply only where investigation proved as a fact that there was waste, as defined in the bill. The bill would apply to all oil fields in the United States and, in my opinion, the need for its enactment would be no less urgent than it is now if all of the States, which do not have oil- and gas-conservation laws should enact them.

The bill proposes an Office of Petroleum Conservation in the Department of the Interior, coordinate in rank with the other major branches of the Department. The relationship of petroleum to the national well-being; its direct connection with the every-day activities of virtually all citizens, whether resident in producing States or in those which only consume petroleum products; the dependence upon petroleum for fuel and lubrication of all facilities of commerce—by water, rail, road, or air; the high rank of the oil industry; and its vital relationship to the national defense all combine to justify the unified administration of all Federal functions pertaining to oil and gas conservation on a basis commensurate with the importance of petroleum among the essential needs and products of the Nation.

In my opinion, the coordination and consolidation of Federal oil activities, as proposed in H. R. 7372, is highly desirable and will provide a real opportunity for effective conservation work in oil and gas. It will make possible the reshaping of Federal oil research, with special emphasis on the prevention of waste and the increased recovery of oil from flowing and pumping fields. It will enable us so to organize our work that we will learn more than we now know about our oil and gas resources, the actual conditions of production, and the waste of oil and gas. I have been told that these hearings have made it quite evident that we need the definite information which could be acquired under the terms of this bill and that a coordination of our departmental oil activities is most important.

There are five agencies in the Department of the Interior whose work is concerned directly with oil. These are the divisions of the Bureau of Mines, engaged in studies of petroleum engineering and economics; those of the Geological Survey, Office of Indian Affairs, and General Land Office in connection with oil and gas leases on public, Indian, and naval-petroleum-reserve lands; and the Petroleum Conservation Division, including the Federal Tender Board, which assists in the administration of the Connally law. In the aggregate these divisions expend annually approximately $1,400,000 and have nearly 450 employees in the field and in Washington, most of whom have been in this work for many years. In addition to the offices in the Interior Department in Washington, there are 26 field offices of varying size. Of these, 6 are in Oklahoma; 4 each in California, Texas, and Wyoming; 2 each in Montana and New Mexico: and 1 each in Colorado, Louisiana, Michigan, and Utah.

The expenditures of State agencies in the administration of State oil- and gas-conservation laws are somewhat more than the Interior Department's expenditure on oil. In the aggregate Arkansas, Kansas, Louisiana, Michigan, New Mexico, Oklahoma, and Texas spend about

$1,750,000 annually in the administration of their oil- and gas-conservation laws. This does not include the costs of the industrial committees directly associated with the State agencies.

It is most important to note that the bill proposes the establishment of a Council on Petroleum Conservation to consist of nine State officials engaged in the administration of petroleum-conservation laws, six producers of petroleum, and three members of petroleum faculties at educational institutions. The Council is to meet annually with representatives of the Federal Government to consider matters which may arise in connection with the prevention of waste in petroleum production or as to the civilian and military petroleum needs of the Nation. The council also is to arrange for the current exchange of information as to production methods and practices which will tend to effect the conservation of petroleum. This pooling of information obtained through the researches of oil producers, colleges and universities, and of State and Federal offices, coupled with experience gained in field operations, will prove effective in the broadening of the knowledge and understanding of oil conservation.

In the main, the bill deals with the definition, investigation, determination, prevention, and correction of waste in oil production. These provisions of the bill, in my opinion, do not deprive oil producers of any right which they have now, other than the right, if it can be so regarded, to produce oil wastefully. The bill so prescribes the factors of waste that any oil producer may review his own operations and, within the reasonable limits of differences in engineering opinion, determine for himself whether or not his operations conform with the standards set forth in the measure. The several producers within a single pool may do likewise and agree voluntarily to a plan of operation for the field. When producers, singly or jointly, do not do this and their operations, upon investigation, are found to be wasteful within the meaning of the bill, full opportunity is provided for hearings, within the Federal judicial district in which the field is located, before regulations may be issued under the bill.

The bill is what its title says it is—one to promote the conservation of petroleum and to provide for cooperation with the States in preventing the waste of petroleum. Its introduction into the Congress was requested by the President of the United States, in his letter of July 22, 1939, to Hon. Clarence F. Lea, chairman of the Committee on Interstate and Foreign Commerce of the House of Representatives. I have been informed that this letter has been placed in the record of this hearing.

In my previous appearances before your committee, I have summarized my views on the conservation of petroleum and the prevention of waste in the production of a resource which is vital to the needs and protection of every citizen and of the Nation. I hope that you will regard those previous statements as part of this presentation. My statements, however, did not equal the clarity with which your committee, in its first report, stated that—

> whether our petroleum supplies are large or small, they should not be physically wasted above or below the ground. Cheap and abundant fuel and power are the very cornerstone of American industry, transportation, and business.

I might have added "defense."

In recommending the enactment of this bill, H. R. 7372, I am mindful of the progress in oil conservation which has been made during the past decade but I am aware also that much has not been done, the doing of which is necessary. I know that a number of States have joined in a compact which has the principal purpose of preventing physical waste in oil and gas production but I am aware of no specific recommendation or action on its part to prevent such physical waste. I would greatly prefer to be able to come before your committee and say that the State authorities and the oil producers were doing a complete job of preventing waste and that there was no need for further concern as to the protection and adequacy of our oil supply, in terms of emergency needs or of normal civilian requirements. I regret that I cannot give you that assurance and that I must stress the need for legislation which will assure adequate protection against avoidable waste of the oil resources of our Nation.

During these hearings, references have been made to existing waste which is the result of past excessive drilling; to wells which have been drilled too closely together, through the granting of exceptions to spacing rules; and to volumes of gas being blown into the air under high pressure from wells which have got beyond the control of the driller or producer. It has been said that the proposed bill could not correct such waste or the conditions which caused it. However, such a statement overlooks the fundamental fact that action under this bill, as stated in section 5–a, is limited to the prevention of avoidable physical waste. It is obvious that Spindletop, Santa Fe Springs, Wilmington, and other closely spaced fields cannot now be redrilled with a more efficient spacing pattern and that regulations cannot stop the flow of gas where there is no mechanical means of doing so. Waste which cannot be prevented or corrected is not avoidable waste and does not come under the bill. However, if this bill is enacted, coordinated action of State and Federal agencies will certainly contribute to the prevention of such occurrences in the future.

It has been indicated also that some wasteful practices may be found in all of the oil fields of the United States and that all industrial processes, including the production of oil, must be accompanied by some degree of waste. From this, it has been implied that, in the administration of this measure, there would be a Federal agent in each oil field of the United States and that Federal engineers would be scurrying around the countryside looking for opportunities to point a finger of guilt at minor and unimportant instances of waste. If the bill is enacted and if I have any connection with its administration, I assure you that there will be no such running around to disturb and annoy and that action to prevent waste will be taken only in those instances where the facts are beyond engineering dispute and where there is a deliberate unwillingness to correct them.

The purpose of the bill is not to supplant State authority with Federal authority. Instances might arise in which there would be elements of conflict between these authorities and, if the matter should reach a point where determination were necessary, it is the intent of this bill that the Federal authority would prevail. It is my opinion, however, that such instances of conflict would be infrequent even at the start and more so as the provisions for coordination become effective. In most instances, the provisions of this bill would be exercised in situations where the State authority had not been applied or where its application was being withheld because of pressures or circumstances beyond the control of those in immediate charge of the State laws.

In instances where State orders will have been issued but investigations under this bill would show that they are ineffective in preventing avoidable physical waste as defined, it would be necessary to have definite proof of that fact. Such proof would have to come after, and not before, the State order had been applied and ordinarily would be sufficient to convince the oil producers and the State authority of the need for modification of the orders of the latter. The point at issue in such circumstances would not be trivial, but would be fundamental and definitely recognizable as such. Such a conflict might arise in a field in which there would be positive evidence of a substantial decline in reservoir pressure, excessive gas-oil ratios, and an approach to the critical point at which gas in solution with the oil could escape underground. If the producers in such a field then should demand that the State authority allow them to produce more oil and the authority should yield and permit the increased withdrawals, even though it were evident that such action would aggravate the already wasteful practices then, in my opinion, the provisions of the bill which you have under consideration should be applied, even to the point of legal action against the producers.

I dislike to connect the idea of crime with the business of producing oil, but I am not alone in believing that waste may come close to being a criminal act. Col. E. O. Thompson, a member of the Railroad Commission of Texas and chairman of the Interstate Oil Compact Commission, said in his recent statement before the T. N. E. C.:

> Really the old methods were so wasteful that looking back it seems almost criminal the way our oil resources were wasted, but it is no worse than was done with the forests and certainly it is not to be mentioned in the same breath with the prolific waste that we have experienced by our lack of conservation in the use of the soil in America * * *.

If and when these old methods continue to be applied in the light of the engineering principles that we know today, even now they may be called "almost criminal." If your committee can find a better way to strengthen the hands of the State authorities and make certain that their appointed task will be done effectively, you may count on my support. I am not favoring this bill because of a desire to do more work or to assume more responsibility. I am doing it because I want to see done well a job which is of vital importance to our Nation.

One final word: The cause of oil conservation can be hampered in no more effective way than by the goadings and proddings of those who attempt to build up the belief that the State and Federal forces stand in opposite camps, ready to grab off this or that power when one or the other may momentarily be looking the other way. This is not so. Those of us in State and Federal offices who have been together for years in administering our respective laws for oil and gas conservation know that we are working together in a common cause.

I have presented my case as clearly as I can and I believe that your field investigation will verify the statements that I have made. I have asked the Solicitor of the Interior Department to prepare a complete brief on the constitutionality of the bill and the Directors of the Geological Survey and the Bureau of Mines to supplement this statement with full reports on present and recent instances of avoidable waste in oil and gas production. These will be submitted as promptly as possible. I know that the interest of your committee in the conservation of oil and gas is no less keen than my own and that you are informed on this subject as well, if not better, than I. I leave the matter in your hands with full confidence that you will do what you deem best for our country.

Mr. COLE. Mr. Secretary, in the concluding part of your statement, the last paragraph, you state the Solicitor of the Interior Department has been asked to prepare a complete brief on the constitutionality of the bill and the Directors of the Geological Survey and the Bureau of Mines to supplement your statement with full reports on present and recent instances of avoidable waste in oil and gas production.

I assume by that, first, you mean that the statements to be received from the Directors of the Geological Survey and the Bureau of Mines are in addition to the work they have already furnished this committee in bringing the investigation of 1934 up to date?

Secretary ICKES. I thought it might be advisable to have them check up and present any new or additional facts.

Mr. COLE. As chairman of the committee, and on behalf of the committee, I want you to know that we appreciate very much the splendid assistance and help which was given to the committee by the employees of the various bureaus of the Interior Department in bringing the technical part of this work up to date.

In discussing the constitutionality of the bill, I hope you will have the Solicitor of the Interior Department refer, if he will, to the question as to whether there is unwarranted delegation of power in this bill, and whether by its terms waste is sufficiently defined.

Secretary ICKES. Yes.

Mr. COLE. I realize that in section 5 (b) it states [reading]:

> Within the meaning of subsection (a) of this section—
>
> (1) Physical waste of crude oil shall be deemed to include the loss or destruction of crude oil—

and so forth.

I am personally a little disturbed as to whether there is sufficient definition in view of recent decisions.

Secretary ICKES. I will have that thoroughly looked into.

Mr. COLE. Mr. Secretary, have you any comment, in addition to your prepared statement, to make as to the advisability of this legislation, in view of recent developments abroad?

Secretary ICKES. Well, I think that what happened in California on Tuesday, when for the second time they defeated a conservation law, is pretty good notice that we cannot expect much from the second largest oil-producing State in the country acting on its own volition. Meanwhile, waste has gone on there and waste continues to go on.

Illinois is in bad shape. They have no conservation law.

Mr. KELLY. It seems to me, Mr. Secretary, that the attitude of the people in Illinois is such as to prevent any regulation whatsoever. I notice in some of the newspapers, and I have here the Herald-Examiner, where it states that the fear of the people is such that landowners are deeply opposed to a proration program, but would cooperate with the State in any reasonable conservation program, but they don't want the major companies to dictate this program.

Secretary ICKES. Well, that would cover one quotation in my formal statement. What is reasonable depends on the point of view, the time, and circumstances.

When people have flush production which they can market without regard to the national interest or without regard to other oil producers, then it is considered by them unreasonable to put on any regulation. And all I intended to say, and I hope I did say in this recital, is that any proposal is always currently regarded as unreasonable, outlandish, foolish, unwarranted, unscientific—choose your own term.

I think that there is a national interest in the production of oil and gas, and also in the prevention of waste, and that the Nation has a right to interest itself in it.

Mr. COLE. You said the Nation has a right to interest itself in it?

Secretary ICKES. Yes; a duty, I would say.

Mr. COLE. Speaking definitely or concretely of the situation in Illinois, if this bill should become law, what power would the Federal Government possess?

Secretary ICKES. Well, in the absence of reasonable regulation by the State, the Federal Government could go in and do what the State has failed to do, to prevent avoidable waste.

Mr. COLE. Yes. As to the necessity for any action of that kind to prevent waste in Illinois, it is a fact, Mr. Secretary, is it not, that the forecast of the demand for oil as released by the Bureau of Mines each month is pretty closely followed by the oil-producing States?

Secretary ICKES. In States that have regulations; yes, that is right.

Mr. COLE. I observed only this week where two members of the Texas commission were in Washington, asking for a 400,000 barrel increase in the production of Texas; that is, that the Bureau of Mines would increase the demand forecast for Texas by that amount.

Secretary ICKES. And if we did that for Texas, we probably would be asked to do it proportionately for every other State.

Mr. COLE. Of course, it suggests to me, in reading the article, that Texas, while there is no demand in law or authority of law to compel them to do that, there is an inclination on their part to try to follow as closely as possible to the figures released by the Bureau of Mines.

Secretary ICKES. Yes; Texas has done that.

Mr. COLE. Speaking of Illinois, the figures before me present this picture: taking the past 9 months of 1939, the estimated demand by the Bureau of Mines for the State of Illinois—the same character of demand which Texas and other States receive and respect—is 86,100, while the actual production of the State for the same month was 143,400.

Secretary ICKES. Precisely.

Mr. COLE. For the month of February the demand was 102,500, and the production, 162,700.

Not giving each month, for all of it will be in the record at the appropriate place, but taking the last 3 months: July 1939, the estimated demand was 187,400, while the actual production was 281,800; about a 45-percent increase.

In August the demand was, as estimated, 201,900, and the actual production was 317,800, or about 60 percent increase over the demand.

In the month of September, the estimated demand was 248,700, and the actual production was 348,000, or over 40-percent increase.

Is it your testimony that in meeting that situation, if this bill is law, that the Federal Government would control the situation in Illinois insofar as it was necessary to control it in preventing avoidable waste of petroleum in that State?

Secretary ICKES. We believe that would be the effect.

Mr. COLE. And the same would apply for the State of California?

Secretary ICKES. That is right. Now they think they have discovered oil in Nebraska. I don't believe there is any conservation law there. It may be a repetition of Illinois.

Mr. COLE. You referred to the interstate compact set-up. The compact, which has heretofore been reported through this committee and approved by Congress, is comprised of the States, without any Federal participation in the compact group.

Secretary ICKES. That is right.

Mr. COLE. Yet in 1934, was it not the case that when the compact was first suggested—I think first suggested by President Roosevelt—and then in the report of this committee, which encouraged it, the compact at that time was recommended to be set up between the States and the Federal Government and that the compact provide for definite Federal representation on the board, did they not?

Secretary ICKES. That is correct.

Mr. COLE. What observation, if any, do you care to make as to the effect of the changed condition throughout the world as far as our country is concerned, since this bill was introduced?

Secretary ICKES. Well, there is likely to be much greater demand from the foreign countries as a result of the present war in Europe. That may have the effect of increased prices, both for crude and gasoline. I don't know; that is merly speculation on my part.

Mr. KELLY. Mr. Secretary, I note your statement on page 26 regarding waste in the Illinois fields. To your knowledge, do you know whether the companies operating there voluntarily space off those fields properly, or are they just drilling wherever they see fit?

Secretary ICKES. My advisers say it is not so much a matter of spacing as it is of methods of operation, which result in waste.

Mr. WOLVERTON. Mr. Secretary, in view of your statement that world conditions will probably create a greater demand, do you advise any change in our law with respect to importation or exportation of oil?

Secretary ICKES. Well, there is nothing in this bill about that. But if I may answer that personally, and not officially, I believe insofar as possible in saving what we have. When it comes to a resource like oil, that is absolutely necessary. We could not conceive of an America now without plenty of reasonably priced oil and gasoline. We are exhausting our reserves faster than any other nation.

I do not think it is sound national policy, Mr. Wolverton, and I think that a determination by Congress of whether or not as a matter of national policy we ought to continue to export oil and its products, as we have been to date, might be very much worth our while.

Mr. WOLVERTON. Of course, I realize that the question is more general and wider in scope than probably the provisions of this bill, but in view of the fact that this committee was appointed under a resolution which is much wider in scope than the actual bill which is before the committee, it would seem appropriate for us to make some inquiry along that line. Of course, if you are not prepared to speak on that larger phase today, then it is not my intention to press the point if you do not wish to do so.

Secretary Ickes. I am not prepared to do more than express my personal opinion, because from my point of view it would be a matter for consideration by the administration, and the administration so far as I know has arrived at no conclusion on that subject. I do not know whether we have even considered it. But personally, I think it would be in the interest of sound national policy to reduce, perhaps even drastically, our exports of petroleum and its products.

Mr. Wolverton. Over a period of years the matter has been given consideration. The question of conservation has been of importance and has been impressed upon us to such an extent that the membership of the committee have felt entitled to consider it, in all of its phases, not merely from the standpoint of limitation of production or the elimination of wasteful methods of production, but also from the larger standpoint as to how far we are justified in using a depletable national resource when there is available the same commodity elsewhere.

In other words the need for conservation has been presented to this committee in such a way as to raise almost a condition of catastrophe, unless something is done. The broadcasts that have been put out by your department build up that thought, a catastrophe, if there is not proper conservation.

That being the case, it would seem to me that the question of exportation and importation is entitled to be considered very seriously.

Secretary Ickes. I think it ought to be.

Mr. Wolverton. Realizing that the basis of all this legislation is conservation, what method does the Government pursue to determine just what the present recoverable supply of oil is in the United States?

Secretary Ickes. I will have to ask for help on that question.

Mr. Swanson, will you answer the question?

Mr. Swanson. Yes, Mr. Secretary.

Secretary Ickes. Mr. Swanson will answer that, if he may.

Mr. Swanson. To the best of my knowledge, the Federal Government has no facility of its own for its own determination of the recoverable oil reserves of this country or of other countries of the world. They depend upon other sources which they believe to be reliable, but so far as I know, in which they do not participate.

Mr. Wolverton. Mr. Secretary, it would seem to me that the need for conservation would depend very largely upon what our source of supply is.

All of the legislation is predicated upon the fact that we have a very limited supply.

Secretary Ickes. That is true.

Mr. Wolverton. Yet it has come to the attention of this committee that, over a period of years, our supply has greatly increased.

If our present depletable supply of oil is to be the basis of a conservation policy, it would seem to me that the Federal Government should be in a position to know definitely, on its own account, as to just where we stand on the question of the recoverable quantity of oil that is known to exist in our several States.

In other words, the testimony has seemed to indicate to us that the figures that are given to us as to the oil supply of the country, known recoverable supply, is based very largely upon figures which are taken from trade magazines and from reports put out by the Petroleum Institute and other sources. It astonishes me and surprises me that the Government itself has no means of ascertaining the exact situation.

Secretary Ickes. Why, I think that the Geological Survey could answer it as accurately as anyone possibly could what our present known reserves are. Of course, anyone can speculate as to unknown, undiscovered reserves, but that would be pure speculation. The belief of Interior is that, on the basis of the present known oil reserves, we have a supply that will last, at the present rate of consumption, for from 15 to 20 years. Now we do not say, we never said, and we won't say that other large supplies exist within the territorial limits of the United States that will not be discovered and be available. There may be a flood of oil. But a prudent man in his own business affairs goes on what he has and what he knows he has, and not on what he may have in 20 years or 30 years or 50 years.

I hope that we are unnecessarily alarmed, but I can see no sound reason, as a matter of public policy, for not preventing waste even if we have 40 or 50 years of oil in sight.

Mr. Wolverton. I am not disagreeing with the emphasis that you place on the necessity of conserving any commodity that is depletable——

Secretary Ickes (interposing). And irreplaceable.

Mr. Wolverton. And irreplaceable; except by discovery and improved methods.

Secretary Ickes. Well, that would not increase the supply.

Mr. Wolverton. In the strict sense of the word, it would not; that is true.

In our legislation of 1935 it has been called to my attention by the chairman (Mr. Cole), and I agree with him, we provided that there should be some method inaugurated by the Government for a determination by the Government officials themselves, by their own examination, of what the oil supply of the Nation is.

In the testimony that has been given to us this week it seems as if that has not been done, but they continue to get their figures from the sources that I have indicated, from private industry.

Secretary Ickes. Well, I do not quite know how we could get figures except from those who discovered the pools and are operating in them.

Mr. Wolverton. The chairman has called my attention to the fact that the provision that I have just referred to was in a bill which the committee reported—

Secretary Ickes. Which did not pass.

Mr. Wolverton (continuing). Which was blocked in the House.

Secretary Ickes. Yes. We have neither the facilities, the money, nor the authority to find out what we would like to know.

Mr. Wolverton. Do you think provision should be made for that kind of a survey by your Department?

Secretary Ickes. I think it would be very desirable.

Mr. Wolverton. In view of the fact that the limitation of production is based, or should be, on the amount of recoverable oil available, it seems to me we should have the basic figure; namely, the amount of recoverable oil known to exist throughout the Nation.

Secretary ICKES. I think, Congressman, that we could rely with pretty complete confidence for our estimates of recoverable oil, known recoverable oil, upon the figures in the industry.

To try to discover new fields of potential supply would be something different.

Mr. WOLVERTON. It may be that we can depend upon the accuracy of the figures that are given by private industry. When you consider that limitation of production has a direct effect upon the price to the consumer; then it would seem to me that you would have to go back and determine whether the limitation was justified on the basis of the amount of oil that existed. There might be in one instance a greater degree of limitation required in the interest of the public or there might be some other legislation required in the interest of the public.

Secretary ICKES. You mean the limitation that keeps it within consumptive demand?

Mr. WOLVERTON. Of course, if you are speaking of conservation as a principle, I have never had it made clear to me why it should be based upon supply and demand alone.

Secretary ICKES. No. We are not basing it upon supply and demand.

Mr. WOLVERTON. I thought that proration——

Secretary ICKES (interposing). As to the difference. In any plan there ought to be an apportionment, a proper apportionment; not a limitation. They are quite distinct. We do not propose to limit except in places like Illinois, for instance, where it will appear that they are producing more than they ought to be producing in comparison with other States which are limiting themselves as between themselves.

Mr. WOLVERTON. Well, of course, if your concern is as to a natural resource which is limited and not replaceable, I do not see how you are going to put it on a strictly conservation basis when you only take into consideration supply and demand, or demand as a basis.

Secretary ICKES. Conservation does not mean limitation below the amount that we can use and ought to use. I define conservation as a prudent use of our national resources, by the present generation, with a view to saving all that we can for future generations.

Now prudent use does not mean a limited use. It means a wise use; a use without waste.

Mr. WOLVERTON. Are you speaking of physical waste or economic waste?

Secretary ICKES. I am speaking of physical waste.

Mr. WOLVERTON. When you speak of prudent use, does not that have reference to economic waste?

Secretary ICKES. Well, it has an economic result, but, for instance, in the long run I do not think it helped Michigan to allow its forests to be denuded.

Mr. WOLVERTON. Suppose, in order that I might get your viewpoint correctly, that the amount to be produced was improperly estimated, in that the demand was less than had been contemplated, does that constitute waste?

Secretary ICKES. Well, it may.

Mr. WOLVERTON. In what way?

Secretary ICKES. Well, it constitutes waste, because the best place to store oil is in the ground. It does not run the risk of fire and of evaporation.

Mr. WOLVERTON. But, if it should happen that the amount produced was greater than the demand, would it be your thought that would be a waste in itself?

Secretary ICKES. No; not necessarily. It might be that they would produce too much in 1 month. It can be put in storage, but the fact that you have that excess in storage seems to me from the point of view of the producers themselves that it ought to be taken into consideration in the next month's production.

Mr. WOLVERTON. Well, the situation that I am endeavoring to lead up to in my questioning on this subject found expression in August last when several of the State commissioners, because of a reduction in price by one of the major oil companies, shut off production entirely. It seems to me that was totally foreign to what had been the purpose of this committee in reporting legislation known as the Connally Act to limit production of oil——

Secretary ICKES. I agree with you.

Mr. WOLVERTON (continuing). Having for its purpose conservation.

Secretary ICKES. They were using a conservation measure in order to affect the price. I did not think it was proper at the time. I think I said something publicly to that effect.

Mr. WOLVERTON. Well, that was my opinion, and it has justified to some extent the arguments that have been made at one time or another before this committee that while this legislation is requested on an idealistic basis as a conservation measure, yet basically the thing that the industry was interested in was not so much conservation as stabilization of price.

Secretary ICKES. I am not prepared to dispute you on that.

Mr. WOLVERTON. And it would seem from the action that was taken by the commissions of the several States last August that they were willing to cooperate in the effort to stabilize prices, regardless of conservation.

Secretary ICKES. I think that is a very sound and eloquent argument for a Federal bill.

Mr. WOLVERTON. I assure you, Mr. Secretary, that I was one of those on this committee who insisted on the provision now in the present bill that in fixing a limitation of production there should be some safety valve in the interest of the public, and we placed a provision in the bill that put power in the President to act under certain circumstances. Evidently you and I are in entire accord on that.

Secretary ICKES. I do not think there ought to be any power to fix prices under this bill or do anything that would have that effect.

Mr. WOLVERTON. That is the thought that I am giving, and have always given, to all of the conservation measures that come before this committee. I am personally in favor of conservation, but not willing that it should be used for purposes other than conservation.

Secretary ICKES. Well, I adhere to the theory that if and when the United States Government should go into price fixing, that it ought to do it not under the subterfuge of a bill that apparently is for some other purpose but do it frankly as price fixing, and I think that they made a mistake in Texas in doing what they did, in closing down production for a period.

Mr. Wolverton. It certainly lent support to the argument that has been made at one time or another that stabilization of price was the real interest some had in these conservation measures.

Secretary Ickes. The Congressman probably would have no reason to remember it, but I gave out two statements on that matter, and in my second statement sounded a warning that it might become necessary for us to invoke the powers under section 4 of the Connally Act because we recognized that the shut-down was not an activity in behalf of conservation at all, but it was for prices.

Mr. Wolverton. I did not see that statement, but it does not surprise me, because it seems to be in accord with the principles you advocate for conservation, and it appeals to me.

Secretary Ickes. Yes; because the danger in a thing like that is that it is likely to discredit the whole conservation theory.

Mr. Wolverton. Your statement makes reference to the fact that the Solicitor of the Department of the Interior will submit a brief on the constitutional questions involved in this type of legislation?

Secretary Ickes. Yes.

Mr. Wolverton. May I ask who is the present Solicitor of the Department?

Secretary Ickes. Mr. Nathan Margold.

Mr. Wolverton. Is he the same gentleman who was the Solicitor when this committee conducted its hearings in 1934?

Secretary Ickes. He has been the Solicitor of the Interior Department ever since I came here.

Mr. Wolverton. I remember his being before us at that time and expressing his opinion as to the constitutionality of conservation based upon or made effective by limitation of production. Subsequently, when we were at Dallas, Tex., there came to our attention a bill that he had drawn, known as the Margold bill, a bill which created a great deal of interest and probably concern on the part of the industry because of the broad character of the bill.

Secretary Ickes. Congressman, that was not a departmental bill.

Mr. Wolverton. I understood that——

Secretary Ickes. It never was put out as a departmental bill. What we did was merely what we would do for any Congressman who sought our drafting facilities. We would draft for him in the Solicitor's office, the best we knew how, a bill embodying his ideas, without underwriting its constitutionality.

Mr. Wolverton. Well, the scope of that bill, it seems to me, has had much to do with the fear that is created when any type of conservation is suggested such as the legislation in 1934.

Secretary Ickes. Well, in 1934, I know of no one who was prepared to go as far as Congressman Marland in an oil-control bill. He was one of the first Members of the House who came down to see me, and he was very strongly of the opinion that we ought to go to the absolute limit in drafting an oil bill and seeking its passage by Congress.

Mr. Wolverton. Was the provision that is in this bill, H. R. 7372, with respect to the elimination of waste, in the Margold bill?

Secretary Ickes. Do you know, Mr. Swanson?

Mr. Swanson. No.

Secretary Ickes. I cannot answer that question, but we will be glad to supply the information.

Mr. WOLVERTON. I do not have a copy of the Margold bill before me or I could probably answer it myself; but, speaking of the fear that I have stated seems to be prevalent with respect to this bill, I call your attention to a statement that is contained in the National Petroleum News, the issue of October 25, 1939, and ask if you wish to make any comment in connection with or respect to it. It reads as follows:

> Nor is this just a question of controlling surplus production in the oil fields that may seem far distant from many marketers. The proposed grant of power to the Federal administration at Washington, to a single man to sit in Ickes' office, would give him power to not only so regulate the flow of crude oil to the refineries but to so regulate the flow of products from the refineries, perhaps even to terminals to bulk plants and perhaps to the consumer. Not only price would be affected but the amount of a refiner's supply of crude, or a marketer's or a dealer's supply of products, would be controlled.

Secretary ICKES. I think whoever wrote that was seeing things at night.

Mr. WOLVERTON. He evidently put it in print so he could remember his dreams.

There also appears in the same issue a statement by one of the oil producers of the Nation. The statement in part is as follows:

> As to pending legislation, I am convinced that neither the industry nor the public would long tolerate the consequences of its application. The Cole bill is cloaked in a harmlessly appearing framework of conservation principles, which could easily be used to establish an indirect but effective dictator form of external rule. The only voice of those regulated would be the weak and futile opinion of a so-called advisory council.

Mr. Secretary, would you care to make any comment as to that?

Secretary ICKES. Well, my only comment on that is, these days whenever a man is opposed to any legislation, if he cannot think of a valid argument, he shouts, "Dictator!" and I do not think that is an argument.

Mr. WOLVERTON. Is there anything in the bill, in your opinion, that would justify either of the two statements that I have read from this magazine?

Secretary ICKES. Congressman, I venture to say that if you go back through the files, you would find just as vehemently expressed opposition to all of these State regulatory laws which now have general acceptation.

I was in California a few days ago and I saw cartoons and newspaper articles, and editorials, referring to me as a dictator. I was trying to get hold of the oil industry in California, if you please, although on a State regulatory measure.

It simply means that as in the past the oil industry wanted to run its own business in its own way, regardless of whether or not it affects the public interest, and if it does not affect the public interest, I would say, "All hail and Godspeed. Let them do it."

But here is an irreplaceable and absolutely vital element of natural resources—I cannot think of any resource that is more necessary to the well-being of the country and welfare of the people, with the possible exception of air and water and sunshine, than petroleum, and I think that the Nation owes it to itself and owes it to future generations to see that preventable waste is prevented.

Now, if that constitutes a dictator, why, I am perfectly willing to be called a dictator.

Mr. WOLVERTON. My purpose in directing your attention to these criticisms is only because of the fact that I assume that those who have that viewpoint will at a later time appear before the committee and express those opinions.

Secretary ICKES. I do not have any doubt of it.

Mr. WOLVERTON. I am anxious wherefore to have your opinion.

Secretary ICKES. I could write their speeches for them before they have made them.

Mr. WOLVERTON. We will not have an opportunity of having you back after you have testified.

Secretary ICKES. I am not particularly sensitive, certainly not to descriptions of that sort.

Mr. WOLVERTON. I hope, Mr. Secretary, that you will not take it in such a personal way as to forget the desire that I have to find out if there is anything in the scope of the bill, the way it is worded, or the possibilities of what it may cover, as to justify to any extent criticism along the lines indicated in the quotations I have read.

Secretary ICKES. Not intentionally, and if there is any such language, I hope that the committee will find it and strike it out, or amend it; and I would like to repeat that if the committee and the Congress can find any better way of conserving oil and gas than is proposed in this bill, why, I would like to join in support of any such bill as that.

Mr. WOLVERTON. To correct any improper or false conclusions that may have been reached with respect to the purpose and scope of the bill, are you able to say that this bill, if enacted, would not have anything to do with the limitation of production of oil as it is now administered by the several State regulatory bodies?

Secretary ICKES. No. As I said in my statement, it would still be up to the States to determine what amount of oil could be produced, provided that there was no avoidable waste. There is the only limitation.

Mr. WOLVERTON. So, this bill does not seek to control, and in your opinion does not control, the cooperative system that is now in operation between Federal agencies and State regulatory bodies?

Secretary ICKES. No; it would be merely further intelligent cooperation.

Mr. WOLVERTON. But, it does not seek to fix in any way the amount of oil to be supplied to the public?

Secretary ICKES. Well, on the limitation that I have already stated, we would not seek to limit production. We would seek to prevent avoidable waste.

Mr. WOLVERTON. The bill then only seeks to deal with waste below ground?

Secretary ICKES. Or above the ground.

Mr. WOLVERTON. I beg your pardon.

Secretary ICKES. Waste of any sort.

Mr. WOLVERTON. Well, the illustrations that you gave of the need of this legislation as appeared in your statement, I thought had relationship to waste below ground.

Secretary ICKES. Well, I would emphasize that. I emphasize that because there is not at present much above-ground waste, but if there should be, why, it would cover that too.

Mr. WOLVERTON. In view of your answer, just what waste above ground do you have in mind that this bill seeks to correct?

Secretary ICKES. Well, there is very little now. I think that from their own point of view, the oil companies might avoid putting some in storage above ground, because of loss by leakage, evaporation, fire hazard, and all that sort of thing. The oil is available in the pool as and when needed, but aside from that, all of the waste that we now find or that we would seek to prevent would be underground waste.

Mr. WOLVERTON. The objection to Federal legislation has not come entirely from the industry. It has also found expression through the representatives of the States.

In view of that fact, is there justification for the criticism that is made that this bill would place the Federal Government in control of the particular subject covered by it instead of the State regulatory bodies?

Secretary ICKES. I do not think so.

Mr. WOLVERTON. For instance, take the unit system of operation. I gather from the witnesses who have preceded you, as well as yourself, that such a system is approved.

Secretary ICKES. Yes, sir; as a system; yes. We enforce it now in the public lands.

Mr. WOLVERTON. From the testimony that came before us day before yesterday, it would seem that there were very few pools that were now being operated on the unit system. I think if I recollect correctly, it was 185 pools of 3,000 existing pools. Thus, while there might be agreement as to the advisability of having such a system, yet, some reason or other it seems to have been difficult to place in operation.

Secretary ICKES. Difficult to make it retroactive.

Mr. WOLVERTON. I beg your pardon.

Secretary ICKES. Difficult to make it retroactive.

Mr. WOLVERTON. The very fact that the system is so generally approved, and yet is not made operative indicates to me that there must be some basic difficulty. I have been endeavoring to find out what the real difficulty is.

There are no State laws as I understand that now compel unit operations. Do you know of any?

Secretary ICKES. No; we have none.

Mr. WOLVERTON. Using that as an illustration, there are no State laws and there is no Federal law on the subject.

Secretary ICKES. There is a Federal law applying to public land.

Mr. WOLVERTON. The only Federal law I know of is one which gives you the authority to approve agreements that have been entered into.

Secretary ICKES. Well, as a matter of practice, we are not inclined to allow any pool on the public lands to be developed now unless there is unitization.

Mr. WOLVERTON. I assume that there is apparent disagreement among your assistants to the back of you, Mr. Ickes.

Secretary ICKES. All right; what is it? I cannot keep my eyes to the front, and back of me also.

Mr. WOLVERTON. I thought there seemed to be disagreement among your assistants.

Secretary ICKES. Am I wrong?

Mr. SWANSON. I shook my head, because your statement, I thought, referred to the Federal law of 1931.

Mr. WOLVERTON. I think it is 1935.

Mr. SWANSON. Which permitted the Secretary to approve an agreement.

Mr. WOLVERTON. Yes.

Mr. SWANSON. Whereas there has been subsequent legislation, the law of 1935, which authorizes the Secretary of the Interior to require agreement. So that I thought you were referring to that.

Mr. WOLVERTON. I did not understand that that law went to the extent of giving authority to require such an agreement on private land.

Mr. SWANSON. Public lands.

Secretary ICKES. Public lands.

Mr. WOLVERTON. That is quite different.

Secretary ICKES. There is no law applying to private lands.

Mr. WOLVERTON. Is my understanding correct that is the limitation? So that there is no Federal law that could make this effective and we would need additional legislation? Do you think that this present legislation that we now have before us, H. R. 7372, would enable the Department to enforce such regulations?

Secretary ICKES. I do not believe so. I think that would be a State matter. I do not think we could do anything with respect to that. We regulate the public lands now.

Mr. WOLVERTON. Under the provisions of this bill the Secretary makes an investigation and then announces his findings of wasteful methods that are existing. Could he, under the provisions of this bill, find the facts to be that wasteful methods were in effect because of the failure to adopt the unit system of operation?

Secretary ICKES. I do not believe so.

Mr. WOLVERTON. Then, I assume there is no intention under the provisions of this bill to take jurisdiction in matters of that kind?

Secretary ICKES. That is correct.

Mr. WOLVERTON. Now, with reference to gas-oil ratios that you laid so much emphasis upon this morning, where there seemed to be in many instances excessive ratios. If the Commissioner, as a result of his investigation, should find such conditions existing, would he have the authority under this act to direct the individual who was operating such a well to desist?

Secretary ICKES. I understand so; is that right?

Mr. SWANSON. Yes, sir.

Mr. WOLVERTON. In the event the individual refused, would it be a matter for the State regulatory body to enforce or the Federal regulatory body, which we are setting up under this bill?

Secretary ICKES. Well, I suspect we would have to go into court about it.

Mr. WOLVERTON. I realize that, but which would be the moving party, the State regulatory body, or the Federal?

Secretary ICKES. Well, if we have the power to enforce the rules and they do not obey them, we would proceed to enforce them, through the Federal courts.

Mr. WOLVERTON. So in that instance, the bill does seek to increase the Federal jurisdiction over wells within a State?

Secretary **Ickes**. Oh, unless it gave us additional power, there would not be any point in having a bill.

Mr. **Wolverton**. But you have already said the bill does not give additional power with reference to unit operations.

Secretary **Ickes**. No; it does not.

Mr. **Wolverton**. And it would seem to me under all of the testimony that has been presented here, especially by Mr. Lindsly, day before yesterday, that great emphasis is sought to be placed upon the value of unit operation.

Secretary **Ickes**. It is a valuable method of operation.

Mr. **Wolverton**. As a conservation means, and of increasing the recoverable oil, as well as fairness between the adjoining parties.

Does the bill seek to cover that?

Secretary **Ickes**. I do not see how we could enforce, under any law, a contractual relationship upon people who already have established rights in a pool.

Mr. **Wolverton**. There may be a distinction between doing that and furnishing them with a gas-oil ratio that must be complied with, but, it is not clear to me.

Secretary **Ickes**. I think the answer to that is this—this may be only one answer; there may be others—that conceivably even without unitization, the people who are taking oil out of a pool can do it without preventable waste.

Mr. **Wolverton**. The point I am making is——

Secretary **Ickes** (interposing). And conversely, even if you have unitization, it does not mean that you would not have preventable waste, because they can all agree to waste.

Mr. **Wolverton**. The point that I have in mind is this—that if the Federal Government goes into a State and exercises jurisdiction over an individual oil owner, it seems to me it would not be a much further step to say that it has that same power to go in and exercise jurisdiction over several owners at the same time.

Secretary **Ickes**. I think that it would be going too far to compel contractual relations among them, and I doubt whether the courts would sustain such a power.

Mr. **Wolverton**. The basic thought that I have is one that has come before the committee so frequently that it seems to me that it goes to the very heart of this bill, and that is just how far the Federal Government can go; and I will look with a great deal of interest to the brief which you state will be submitted with respect to that.

This is a departure. It is an advanced step over any legislation that we have taken and, assuming that it is desirable and necessary, can we do it, as a Federal body?

That is a question that I assume your Solicitor General will give his attention to.

Secretary **Ickes**. We will submit a brief on that.

Mr. **Wolverton**. The reason for presenting this bill, I assume from your statement, is the fact that you have not had the cooperation of the States with respect to this matter.

Secretary **Ickes**. I do not think that the States have done all that they might have done.

Mr. **Wolverton**. I take it from your statement that they had done nothing, and for that reason the Federal Government feels justified in stepping in.

Secretary ICKES. Well, I would not say that. They have effected in various States, as my statement showed, oil and gas ratios which seem to vary between States: seem to vary as between fields in the same State; and which do not seem in all instances to be respected by the producers and, in the statement of Mr. Lindsly, it was shown that in particular instances it was not necessary to waste so much gas in order to produce a barrel of oil.

Mr. WOLVERTON. The fact remains that you consider it necessary to have better regulation so that it will be effective?

Secretary ICKES. That is true; but I am not complaining of lack of cooperation. There has been nothing to compel cooperation in that matter. I do not complain of it because of that.

Mr. WOLVERTON. The present Connally Act is based upon cooperation between the Federal and State authorities. Do you think that the authority you now have with reference to waste could be woven into that bill and made a part of that, in such a way as to provide cooperation between the Federal Government and the States?

Secretary ICKES. I am not prepared to answer that question, because I have not considered it. It may be possible, but I consider this really as a measure looking toward cooperation within a broader field than we have under the Connally law.

Mr. WOLVERTON. In view of the fact that the use of oil, as you have pointed out, has national scope, it justifies very serious consideration as to whether the Federal Government in the final analysis is not because of that fact the proper authority to exercise control; but we have not taken that step yet.

Secretary ICKES. No; we have not taken that step.

Mr. WOLVERTON. Under the Connally Act we adopted a cooperative method which, generally speaking, has worked out satisfactorily, I think.

Secretary ICKES. Yes; but where a State has no conservation law which gives the State body the power to fix quotas, we cannot cooperate.

Mr. WOLVERTON. That is true.

Secretary ICKES. As in the cases of Illinois and California.

Mr. WOLVERTON. Then we would have to decide in that case, as well as this, whether it was a proper field for the Federal Government to step in.

Secretary ICKES. Precisely.

Mr. WOLVERTON. We failed in that effort, or at least that effort was made, when the original legislation was introduced, and what finally passed Congress was a compromise by making it a cooperative effort instead of direct action by the Federal Government. That compromise was due to the fact that there was strenuous objection made by the States that the Federal Government was trespassing on their rights.

Secretary ICKES. Well, there was some objection there; but the main objection came from the oil operators who, in 1933, when oil got as low as 5 cents per barrel in the east Texas field, were pretty nearly ready to hand the whole business over to the Federal Government.

Mr. WOLVERTON. Of course, that made some of us think that their intention regarding conservation was based on desire for stabliziation.

Secretary ICKES. I think that their desire for conservation varies with time and locality.

Mr. WOLVERTON. And conditions.

Secretary ICKES. Illinois will be in favor of conservation, you know, after the flush production is all out, and some other field comes in to compete with Illinois; so will California. I feel that I can talk about Illinois, because it is my State.

Mr. WOLVERTON. I think you are right in your prophecy.

Secretary ICKES. Precisely.

Mr. WOLVERTON. Well, I do not care to prophesy what it would be, but maybe you would, coming from Illinois.

Secretary ICKES. Well, there is a good deal of politics mixed up in the oil situation in Illinois.

Mr. WOLVERTON. And that does not always produce sanity?

Secretary ICKES. No; it has not in this case.

Mr. WOLVERTON. Now, what I have in my mind is this, that the legislation we have already passed, which was important legislation, was on a cooperative basis; but this legislation takes an advanced step and in the final analysis in this important matter it is left to the Federal Government to be the final judge as to what is waste.

Secretary ICKES. And I think the justification for taking that step is that the whole oil industry is affected with a national interest. Our very life as a Nation may depend upon having an adequate supply of cheap oil in the not unpredictable future.

Mr. WOLVERTON. The Connally Act is helpful to the States because of the help that is given by the Federal Government.

Secretary ICKES. In the enforcement of their own laws.

Mr. WOLVERTON. Yes.

Secretary ICKES. That is right.

Mr. WOLVERTON. Now, I am wondering if a provision of this kind could not be made obligatory upon the States, if we want to have it made effective.

Secretary ICKES. That would presuppose additional legislation in the various States.

Mr. WOLVERTON. I beg your pardon.

Secretary ICKES. That presupposes additional legislation in the various States, but in view of our difficulty in getting even simple conservation laws in some States, it looks to me to be almost insurmountable.

Mr. WOLVERTON. I assume that as we continue our hearings it will develop as to whether there is a basis on which it could be worked out and could be done, or whether any other method could be worked out. I do not see at the present moment just how it could best be done.

Secretary ICKES. Nor do I.

Mr. WOLVERTON. But I suppose we will have lots of information presented to us in the course of these hearings, some of which may be helpful and some distracting and confusing.

I thank you very much, Mr. Secretary.

I also appreciate your appearance, because you speak with frankness.

Secretary ICKES. Well, I acquired the habit early. I have not been able to get over it to a sufficient degree to be a good politician.

Mr. COLE. Mr. Secretary, recently in discussing the increased needs for petroleum—you referred to the large number of automobiles being used today as compared with past years. In reading a magazine which has just come to my attention, I find this reference to that statement which I use to conclude your participation in these hearings, for it will leave all of us in a good humor [reading]:

> The New York Times discussing Secretary of the Interior Ickes' announcement that automobiles will replace or supplement all horses on Federal ranges, beginning in the spring, presenting an up-to-the-moment version of Home On the Range, as follows:
>
> Home, home on the range
> Where the Fords and the Cadillacs play,
> Where the galloping herd is politely chauffeured
> And the cowboy beds down his coupe.

[Laughter.]

Secretary ICKES. Well, if I said that, I did it very well. I did not know, frankly, that I had given out anything on the subject, any statement, but it is all right.

Mr. COLE. Thank you very much, Mr. Secretary.

Secretary ICKES. Thank you.

## STATEMENT OF RALPH J. WATKINS, NATIONAL RESOURCES PLANNING BOARD—Resumed

Mr. COLE. Mr. Watkins.

Mr. WATKINS. Mr. Chairman, we have one remaining witness, Dr. Glenn E. McLaughlin. I should like to remind you, however, that Mr. Lindsly asked permission to insert his complete paper in the record.

Mr. COLE. Yes; that has been done, I understand.

Mr. WATKINS. Dr. McLaughlin has a paper that he would like to have inserted in the record, but he will read only about 30 minutes' worth of it.

Mr. COLE. You are going to put it all in the record, the committee is anxious to adjourn.

(The statement of Mr. McLaughlin above referred to appears in the record just preceding adjournment of the preceding day's hearings.)

Mr. WATKINS. Mr. Chairman, I would like to introduce in the record an excerpt from the article by Mr. Frank Phillips, which has been referred to by Congressman Wolverton a time or two. Day before yesterday, you will recall, Congressman Wolverton read a quotation from that article, which appeared in the National Petroleum News, October 25, 1939, and I believe the same quotation was read this morning. I think it is in point to say that in that article Mr. Phillips did go on to suggest alternative Federal legislation, and this is the statement that, with your permission, I would like to get into the record:

> One should not render specific criticism of any proposal unless he is willing to offer rather definite suggestions as an alternative. For this reason, at least in part, I knowingly resort to the hazard of inflexibility by describing one possible plan for your consideration and improvement. I definitely emphasize, however, that this proposal is not a finished plan. It must be modified, detailed, and improved to fit all needs. * * *
>
> This suggested plan must be regarded only as symbolic of a process which might enable the industry to continue those duties it is best qualified to perform. The Federal Government then would supply only such compelling force as others are powerless to provide—a police power that exerts itself only when needed. * * *
>
> To achieve this kind of self-regulation under Government sanction, there must

> be legislation essential to a proper conservation of petroleum resources, on the one hand, and legislation essential to good trade practices on the other. * * *

Now, I am concerned here only with what he has to say about conservation legislation; and, incidentally, may I say, Mr. Chairman, that I am not a spokesman for Mr. Phillips. I have never seen Mr. Phillips. I have never corresponded with him; but since he has been the subject of a good deal of discussion, I thought it would be in point to introduce this into the record.

Mr. WOLVERTON. Is there anything there that he says in favor of this bill?

Mr. WATKINS. No; not at all; but the point is that he is in favor of Federal legislation in some form.

Quoting further:

> 1. Existing State agencies now function under State laws designed to regulate exploratory, production, transportation, and storage methods and practices, in the interests of waste prevention, should be permitted to continue their present functions without interference from the Federal Government.
>
> 2. The exploratory, producing, transportation, and storage methods and practices within each of the producing States that has failed to enact its own laws effecting such control should be regulated by a Federal agency acting under the authority of appropriate legislation. In aid of enforcement this legislation should contain a provision patterned after the Connally Act prohibiting movement in commerce of oil or the products thereof produced in violation of rules and regulations promulgated by the Federal agency.

Further provisions for suggested Federal legislation followed these in the article, but they are not essential to my argument. At an earlier point in the article, Mr. Phillips had this to say about existing Federal legislation:

> Such specific legislative steps as have been taken thus far, though still inadequate, have met with little, if any, real objection from the industry or the public.
>
> An interstate compact of oil-producing States has been established by legislative action, but it is without power. * * * Many of those who now think they do not favor Federal cooperation in any form, shuddered recently at the possibility that the term of the Connally Act might not be extended. That act imposes a degree of Federal participation. It does what no unit of the industry or no State can do alone. Unfortunately, it applies only to operators in those States which believe in conservation * * * It does not restrain those who choose to take advantage of the situation.
>
> Because there is no other compelling force upon which to rely for the regulation of petroleum imports, the industry itself has sought the Federal commerce power for regulating this increasingly important factor in the national crude supply. How many now feel that this phase of Federal regulation should be removed?

Mr. Chairman, I should like to thank all the members of the committee for the courteous hearing you have given us.

Mr. COLE. Dr. Watkins, you were out of the room when I made a statement as to Dr. McLaughlin testifying later.

Mr. WATKINS. Yes, sir.

Mr. COLE. The statement was that he would be requested to appear later as the committee has some questions to ask him. So we hope to see you gentlemen in January, and hear more from you on this subject at that time.

Mr. WATKINS. Thank you, Mr. Chairman.

Mr. COLE. The committee will stand adjourned to meet at the call of the chairman.

(Thereupon, at 12:40 p. m., the subcommittee adjourned to meet at the call of the chairman, as above indicated.)

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